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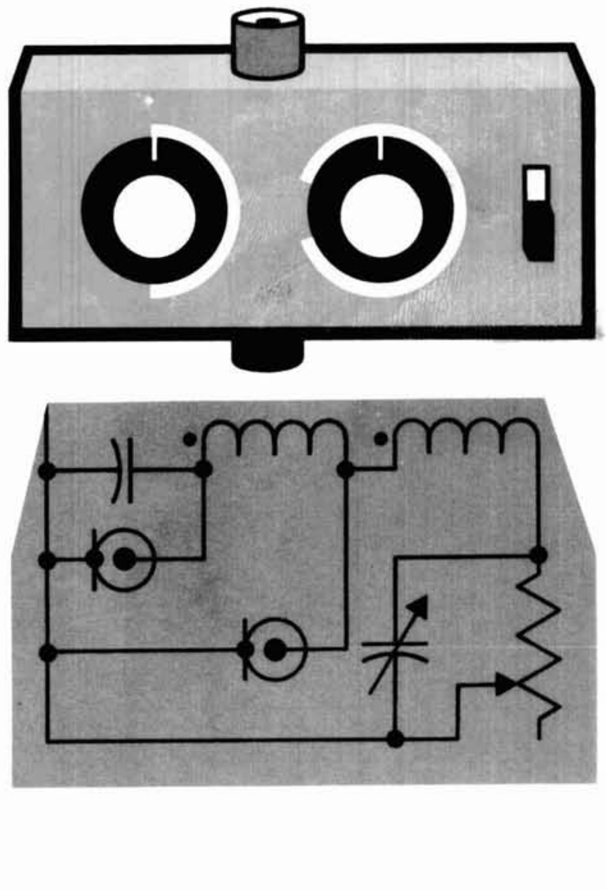
ham radio

magazine

FEBRUARY 1977

accurate rf noise bridge



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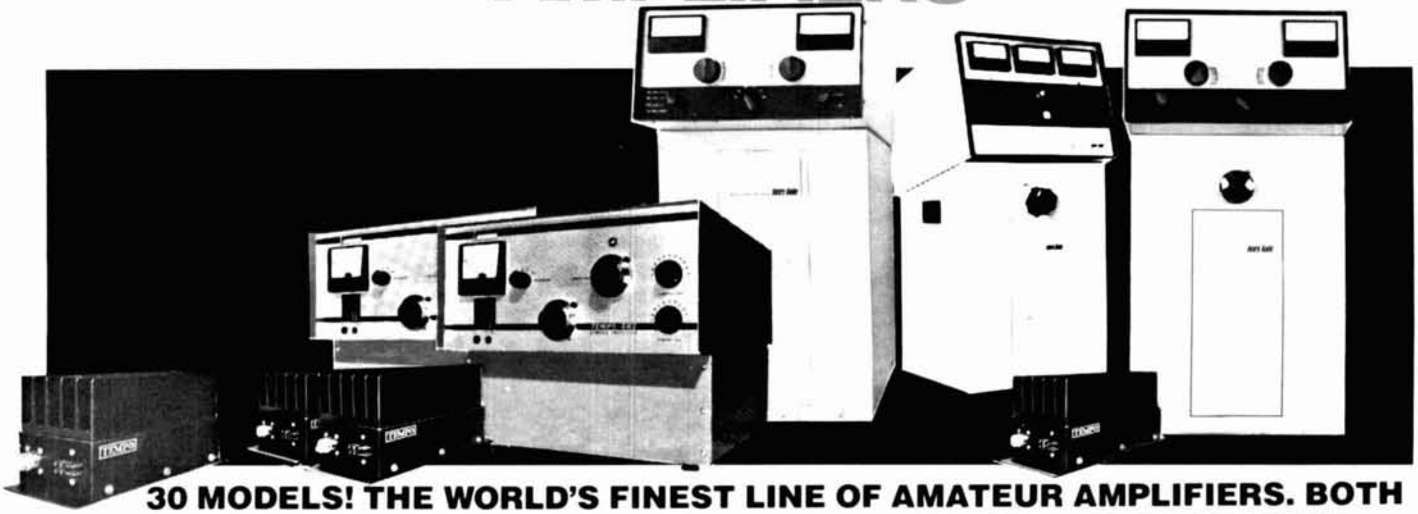

30 MODELS! THE WORLD'S FINEST LINE OF AMATEUR AMPLIFIERS. BOTH VACUUM TUBE AND SOLID STATE...FOR HF, VHF AND UHF...FIXED STATION AND MOBILE...LOW POWER AND HIGH POWER. NEVER BEFORE HAS ONE COMPANY MANUFACTURED SUCH A BROAD LINE OF AMATEUR AMPLIFIERS

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Tempo 100C30	30W	100W	$159.	Tempo 100C10	10W	100W	$149.
Tempo 100C02	2W	100W	$179.				
HIGH BAND VHF AMPLIFIERS (135 to 175 MHz)							
Tempo 130A30	30W	130W	$189.	Tempo 80A02	2W	80W	$159.
Tempo 130A10	10W	130W	$179.	Tempo 50A10	10W	50W	$ 99.
Tempo 130A02	2W	130W	$199.	Tempo 50A02	2W	50W	$119.
Tempo 80A30	30W	80W	$149.	Tempo 30A10	10W	30W	$ 69.
Tempo 80A10	10W	80W	$139.	Tempo 30A02	2W	30W	$ 89.
UHF AMPLIFIERS (400 to 512 MHz)							
Tempo 70D30	30W	70W	$210.	Tempo 40D01	1W	40W	$185.
Tempo 70D10	10W	70W	$240.	Tempo 25D02	2W	25W	$125.
Tempo 70D02	2W	70W	$270.	Tempo 10D02	2W	10W	$ 85.
Tempo 40D10	10W	40W	$145.	Tempo 10D01	1W	10W	$125.
Tempo 40D02	2W	40W	$165.	Linear UHF models also available			

TEMPO 100AL10 VHF LINEAR AMPLIFIER

Completely solid state, 144-148 MHz. Power output of 100 watts (nom.) with only 10 watts (nom.) in. Reliable and compact ...$199.00

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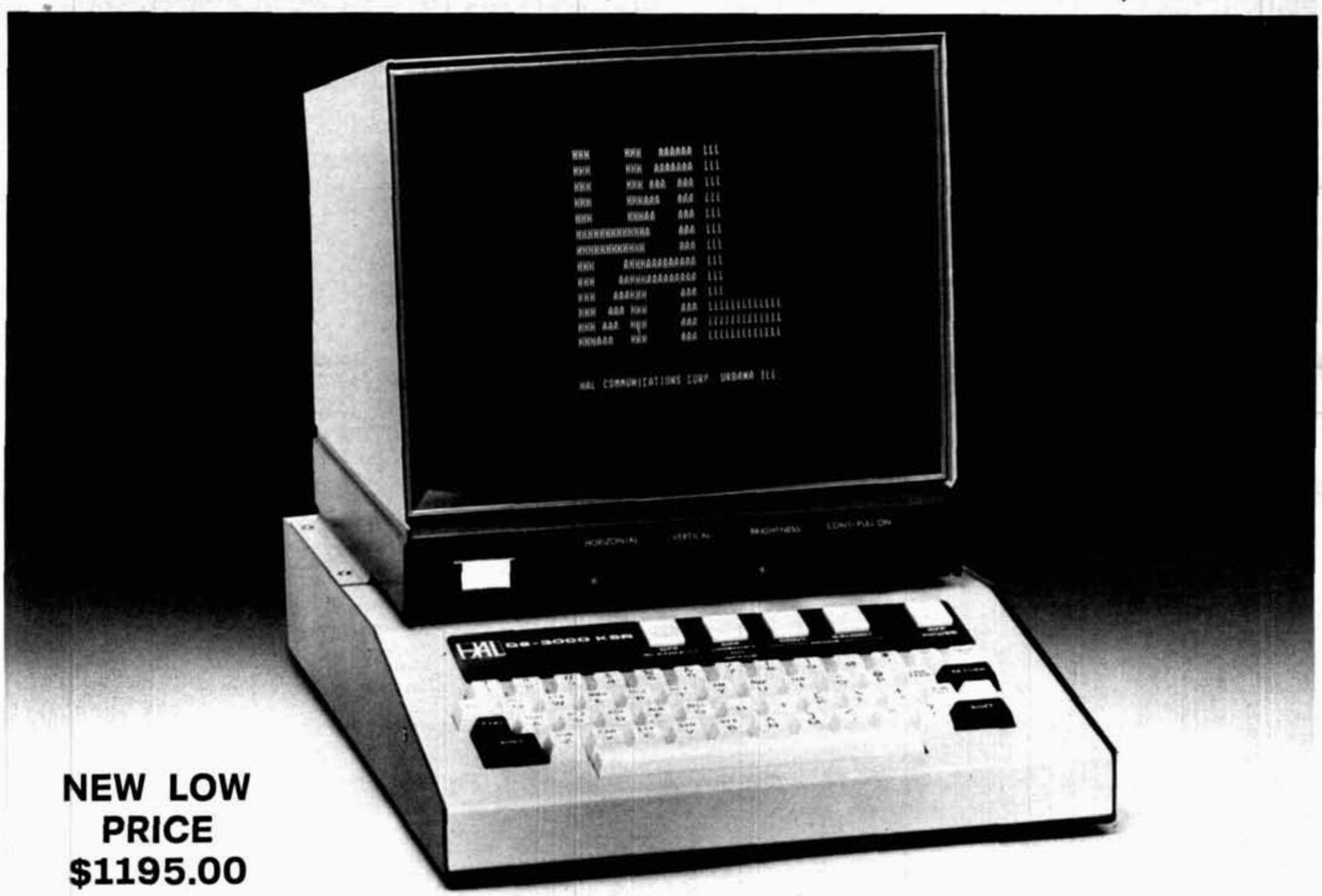

The HAL ST-6000 demodulator /keyer and the DS-3000 and DS-4000 KSR/RO series of communications terminals are designed to give you superlative TTY performance today —and in the future. DS series terminals, for example, are re-programmable, assuring you freedom from obsolescence. Sophisticated systems all, these HAL products are attractively priced—for industry, government and serious amateur radio operators.

The HAL ST-6000 operates at standard shifts of 850, 425, and 170 Hz. The tone keyer is crystal-controlled. Loop supply is internal. Active filters allow flexibility in establishing different tone pairs. You can select AM or hard-limiting FM modes of operation to accommodate different operating conditions. An internal monitor scope (shown on model above) allows fast, accurate tuning. The ST-6000 has an outstandingly high dynamic range of operation. Data I/O can be RS-232C, MIL-188C or current loop.

The DS-3000 and DS-4000 series of KSR and RO terminals provide silent, reliable, all-electronic TTY transmission and reception, or read-only (RO) operation of different combinations of codes, including Baudot, ASCII and Morse. The powerful, programmable 8080A microprocessor is included in the circuitry to assure maximum flexibility for your present needs —and for the future. The KSR models offer you full editing capability. The video display is a convenient 16-line format, of 72 characters per line.

These are some of the highlights. The full range of features and specifications for the ST-6000 and the DS series of KSR and RO terminals is covered in comprehensive data sheets available on request. Write for them now—and tune in to the most sophisticated TTY operation you can have today... or in the future.

HAL

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More Details? CHECK—OFF Page 118

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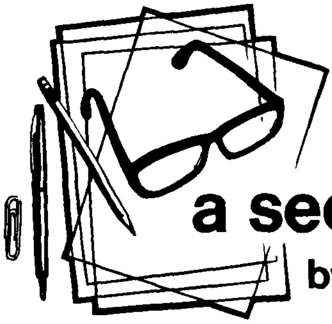

a second look

by Jim Fisk

In its own way, Amateur Radio is starting to face one of the same problems that confronts everyone else in the world — pollution. We are squeezing more and more people into the same amount of frequency spectrum, and this is creating a congested mess for the Amateur operator. Mode and QSO battles rage every night with CW on top of RTTY, one net against another, and contester vs casual operator.

Some Amateurs have been looking for the 1979 World Administrative Radio Conference to alleviate congestion by expanding the Amateur bands, but as you can see in this month's presstop, it doesn't look promising. That means we've got to put modern technology to work to clean up our own act. We should be pushing for cleaner emissions from transmitters, and receivers that are able to cope with the overcrowding. However, the basic question arises, "How do you realistically compare various Amateur equipment?" Quite frankly, with things the way they are now, you can't.

Each manufacturer wants to sell his equipment with its own special features, and the published performance specifications naturally reflect *those* features. As a point of fact, the art of specification writing hasn't kept up with technology; gone are the days when receiver sensitivity and selectivity were the only things you looked for in a receiver — today's receivers must contend with an abundance of closely-spaced, strong signals, but receiver "specmanship" has changed little since the 1930s. The problem is compounded by the fact that manufacturers seldom use similar methods to test their products!

The problems of comparing transmitters is minimal because the published specifications are relatively straight forward: Essentially so many watts at some level of intermodulation distortion, during a two-zone test. This is a basic testing procedure that produces understandable, comparable results. However, there's still room for improvement. What is the impedance-matching range of the output tank circuit, for example, or the dynamic characteristics of the ALC circuit?

Receivers pose a much larger problem. The ads for Amateur receivers still reflect the age-old sensitivity/selectivity hangup — performance features that don't tell you how well the receiver is going to stand up under the high signal density of the real world. Some of today's more notable writers add further confusion by designing so-called "super" receivers and testing with different methods to different standards.

As it is, the problems cannot really be laid at the feet of any one group. Conversations with manufacturers indicate that there is a lack of authoritative information on the subject, so they are generally in a quandary when it comes to receiver testing. The commercial receiver manufacturers are faced with much the same problem, and many have turned to the standards established by the English Ministry of Posts and Telecommunications, or the German FTZ (their equivalent to the FCC). Recently some receiver standards have been set up for Marine equipment, but there's nothing available for the high-frequency bands.

In our studies of this problem, the cooperation of Amateur Radio manufacturers has been outstanding. One manufacturer even said that he would try to get any usable set of receiver test standards accepted by his company! Only one offered any resistance, and he refused to discuss the issue, apparently feeling that any disclosure of his testing methods would reveal proprietary information about his equipment.

What's needed by the Amateur Radio industry is a good set of methods and standards that will be followed by everyone. A recent article by W7ZOI (*QST*, July, 1975) lays down a good set of guidelines for checking the sensitivity, blocking, and IMD characteristics of a receiver, although the article has evidently been largely overlooked. With a little refinement to adequately cover all pieces of equipment, this would provide an excellent starting point. Obviously someone has to spearhead the effort to improve standards for Amateur equipment, and we at *ham radio magazine* are willing to serve as a clearinghouse for your ideas. If we can get our heads together, perhaps we can pound out a set of specifications that will make all of our lives easier when it comes time to buy new equipment. And in the long run, a realistic set of standards will inevitably result in better Amateur equipment for all of us.

Jim Fisk, W1DTY
editor-in-chief

ICOM INTRODUCES THE REVOLUTION IN VFO TECHNOLOGY

Introducing the IC-245, 144-148 MHz FM Transceiver

The VFO Revolution goes mobile with the unique, ICOM developed LSI synthesizer with 4 digit LED readout. The **IC-245** offers the most for mobile on the market. The easy to use tuning knob moves accurately over 50 detent steps and assures excellent control as easily as steering the vehicle. With its optional adapter, the **IC-245** puts you into all mode operation on 12V DC power with a compact dash-mounted transceiver. In FM, the synthesizer command frequency is displayed in 5 KHz steps from 146 to 148 MHz, and with the side band adapter the step rate drops to 100Hz from 144 to 146 MHz. For maximum repeater flexibility, the transmit and receive frequencies are independently programable on any separation. The **IC-245** even comes equipped with a multiple pin Molex connector for remote control.

The **IC-245** is a product of the revolution in VFO design, from its new style front panel, to its excellent mechanical rigidity and Large Scale Integrated Circuitry. Your **IC-245** will give you the most for mobile.

SPECIFICATIONS

GENERAL	
Frequency Coverage	**144.00 to 148.00 MHz*
Modes	*FM (F3)* **SSB (A3J), CW (A1)*
Supply Voltage	*DC 13.8V ±15%*
Size (mm)	*90H x 155W x 235D*
Weight (kg)	*2.7*
TRANSMITTER	
TX Output	*F3 10W* **A3J 10W (PEP), A1 10W*
Carrier Suppression	*40 dB or better*
Spurious Radiation	*−60 dB or less below carrier*
Maximum Frequency Deviation	*±5 KHz*
Microphone Impedance	*600 ohms*
RECEIVER:	
Sensitivity	**A3J, A1 0.5 microvolt input gives 10 dB S+N/N or better* *F3 0.6 microvolt or less for 20 dB quieting S+N+D/N at 1 microvolt input, 30 dB*
Squelch Threshold	*−8 dB or less (F3)*
Spurious Response	*−60 dB or better*
SYNTHESIZER:	
Frequency Range	*144 MHz to 148 MHz*
Step Size	*5 KHz for FM* **100 Hz or 5 KHz for SSB*
Stability	*per C in the range of −10 to +60 C, ±0.0000145% per C*

* Valid with SSB Adapter only

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presstop

SUSPENSION OF FCC LICENSE FEES went into effect January 1st. The fee suspension applies to all FCC licenses — broadcast and commercial as well as Amateur and CB. It's the result of a Federal District Court decision stemming from a suit brought by cable TV and other interests who had charged that the FCC's fee structure was arbitrary and thus improper.

Duration Of The Suspension will probably depend on Congressional action to provide guidelines, and details are still being worked out. Suspension of license fees could favorably affect the growth rate of Amateur Radio if historic relationship between license fees and applications still hold. Amateurs who plan to apply for licenses or license renewals are requested not to send any fees with their applications.

AMATEUR FREQUENCY ALLOCATIONS PROPOSED in FCC's long-awaited Third Notice of Inquiry concerning the 1979 World Administrative Radio Conference don't provide us with the hoped for new HF bands but do expand some of the most important present bands. Perhaps the most significant change is the moving of several lower band edges down: two totally new allocations, one LF and the other in UHF, also offer intriguing possibilities.

A Band-By-Band Breakdown, shows the FCC plans to propose the following Amateur assignments:

1600 Meters:	160-190 kHz (new, exclusive)
160 Meters:	1750-1800 kHz (new, shared), 1800-1900 kHz (exclusive), 1900-2000 kHz LOST
80 Meters:	3500-3900 kHz (exclusive), 3900-4000 kHz (shared)
40 Meters:	6950-7000 kHz (new, exclusive), 7000-7100 kHz (exclusive), 7100-7300 kHz (shared)
20 Meters:	13950-14000 kHz (new, exclusive), 14000-14350 kHz (exclusive), 14350-14400 kHz (new, exclusive)
15 Meters:	20700-21000 kHz (new, exclusive), 21000-21200 kHz (exclusive), 21200-21450 kHz LOST — but, encouraging informal discussions with Maritime people (who were to take the 21.200-21.400 MHz segment) suggest they may take 20.650-21.000 MHz instead, leaving 21.000-21.450 MHz exclusively Amateur, as it is now.
10 Meters:	28000-29700 kHz (exclusive, no change)
6 Meters:	50.0-54.0 MHz (exclusive, no change)
2 Meters:	144-148 MHz (exclusive, no change)
1¼ Meters:	220-225 MHz (shared, with radio-location and land mobile — read that Class E CB!)
3/4 Meter:	420-450 MHz (shared, with some change in priority)
3/8 Meter:	902-928 MHz (new, shared), 935-938 MHz (new, exclusive)

Above 1 GHz, All The Bands we presently have are included in the proposal along with specific sub-bands for the Amateur Satellite Service. The Notice of Inquiry also proposed that the present microwave allocations, except for 48-50 GHz, be world wide to encourage international exchanges between Amateur researchers.

REQUESTS FOR MULTIPLE NOVICE exams must be accompanied by the name and necessary qualifications of the person (or persons) planning to administer the exams, names of the individuals to be examined and the date you expect to administer the exams. FCC reports they've been getting a number of exam requests such as "I'll need a dozen or so exams in the next six months" which they've had to reject.

PROPOSED FURTHER DE-REGULATION of the Amateur Radio Service has emerged from the FCC in the form of Docket 21033 which would revise Part 97 of the FCC Regulations to:

Permit repeater, auxiliary, and remote control operation of Amateur stations under Primary, Secondary, and Club station licenses, and to continue the issuance of separate licenses for such operations;

Delete the requirement that the transmissions of so-called "open" automatically-controlled repeater stations be recorded and the recordings be retained for a 30-day period, and making minor revisions to the logging requirements for remotely-controlled stations; and

Allow Amateur licensees greater flexibility in the choice of frequencies for repeater and auxiliary station use.

The Commission Also Invited comments on the adequacy or the like of current spectrum-management techniques in the Amateur Service. Comments are due by April 1, 1977 and reply comments are due by April 15, 1977.

AMSAT'S A-OD ORBIT is expected to have the following parameters if preliminary calculations are correct: Period — 102 minutes; Apogee — 915 km (567 miles); Perigee — 830 km (515 miles); and an angle of inclination to the equator of 99 degrees. The sun-synchronous satellite is expected to have a DX "range" of approximately 6440 km (4000 miles). LANDSAT C launch expected October, 1977.

DenTron amateur radio products have always been strikingly individual. This is the result, not of a compulsion to be different, but of a dedication to excellence in American craftsmanship. This dedication now extends to one of the worlds finest high performance Military amateur amplifiers.

Luxury styling, however, would not be fully appreciated without an exceptional power source. The heart of the MLA-2500 is a heavy duty, self-contained power supply.

Compare the MLA-2500. It has the lowest profile of any high performance amplifier in the world. It's modular construction makes it unique, and at $799.50 it is an unprecedented value.

Very few things in life are absolutely uncompromising. We are proud to count the DenTron MLA-2500 among them. And so will you.

MLA-2500 FEATURES

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The linear amplifier beyond compromise.

Amplifier in actual operation.

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More Details? CHECK—OFF Page 118

IT'S TIME TO RECONSIDER THE TS-700A

You probably have considered purchasing an all-mode, 2-meter transceiver, but figured that you couldn't afford one. Figure again! Kenwood has lowered the price of the fabulous TS-700A, making it much easier to get on the 2-meter band with a top quality all-mode VHF system. At its new low price, the TS-700A is certainly the ''Pacesetter'' in both price and performance. And it's ready for immediate delivery . . . in fact, your dealer probably has them in stock right now. There's a lot of excitement on 2 meters . . . not only on FM, but SSB and CW too.

Check with your nearest authorized Kenwood dealer for the TS-700A's new low price.

- Operates all modes: SSB (upper & lower), FM, AM, and CW
- Completely solid state circuitry provides stable, long lasting, trouble-free operation
- AC and DC capability. Can operate from your car, boat, or as a base station through its built-in power supply
- 4 MHz band coverage (144 to 148 MHz) instead of the usual 2
- Automatically switches transmit frequency 600 KHz for repeater operation. Just dial in your receive frequency and the radio does the rest . . . Simplex repeater reverse
- Or do the same thing by plugging a single crystal into one of the 11 crystal positions for your favorite channel
- Outstanding frequency stability provided through the use of FET-VFO
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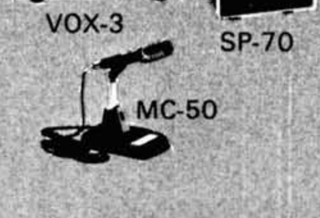
- Complete with microphone and built-in speaker

These fine accessories are also available for use with your TS-700A.



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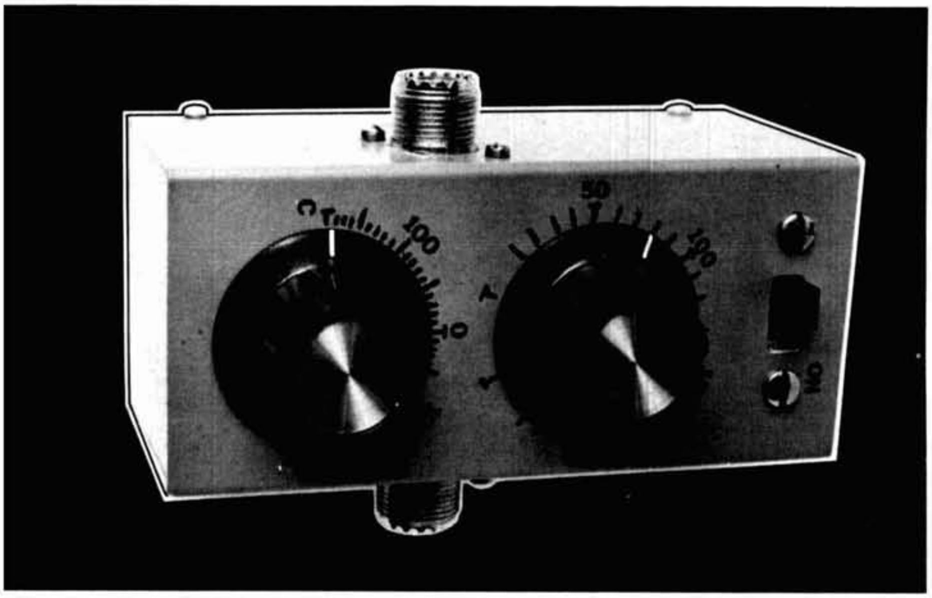


improvements to the RX noise bridge

Circuit and construction improvements for this simple device improve accuracy and measurement range for impedance measurements from 3.5 to 30 MHz

How often have you wanted to know the exact impedance – both the resistive and reactive components – of your high-frequency antenna? Although the venerable swr meter recognizes the situation which makes the transmitter happy, it very often is misleading with regard to actual antenna resonance and related matching adjustments. Amateur literature has approached the subject of measuring complex impedance in the high-frequency range a number of times. In spite of all this, the use of these techniques by amateurs is still relatively uncommon. This is indeed unfortunate, since many antenna adjustments become systematic if resistance and reactance are accurately known.

The rf noise bridge is one of several devices that can be used to make this type of measurement. YA1GJM's excellent article originally got us interested in this device.[1] Subsequently, we have pursued modifications to the instrument which both improve its accuracy and extend its range. Ultimately, an rf noise bridge unit resulted which has the following significant characteristics:

1. Measurement accuracy of 3 ohms rms* for both the resistive and reactive components of representative rf loads.

A parts kit for the noise bridge is being made available in conjunction with this article. For information and prices write to G. R. Whitehouse & Co., 10 Newburg Drive, Amherst, New Hampshire 03031.

By Robert A. Hubbs, W6BXI, and A. Frank Doting, W6NKU. Mr. Hubbs' address is 2927 Roberta Drive, Orange, California 92669; Mr. Doting can be reached at 13031 Ranchwood Road, Santa Ana, California 92705

2. Capability, from 3.5 to 30 MHz, to measure complex impedances equivalent to any point within a 5:1 swr circle on a Smith chart with a $Z_o = 50$ ohms.

3. A calibration concept which does not require laboratory standards and is valid over the entire frequency range up to 30 MHz.

4. Construction cost under $20.00.

With reasonable care, anyone can achieve these same results. All you have to do is follow the instructions on construction and calibration which are included in this article. In addition to these tips we will cover a wide range of other topics relative to the noise bridge. The first two sections describe the basic principles of the noise bridge and some history regarding its development. The next three sections describe our principal contributions — extending the range and improving the accuracy of the instrument. Details on how to build, checkout, calibrate, and use the improved instrument are concentrated in the last three sections.

noise bridge description

An rf noise bridge may be used to measure complex impedances — normally a very difficult thing to do without laboratory instruments. It works as shown in the block diagram of **fig. 1**. An unknown impedance to be measured is connected to the input terminal of the bridge; a receiver is connected to the output terminal where it is used as a sensitive, frequency-selective detector. Contained within the bridge is a wideband noise source which provides a signal over the frequency range of interest. Reference devices with known rf impedances are used to balance the bridge section and to measure the unknown impedance.

A schematic diagram of the bridge portion is shown in **fig. 2**. It works in the following manner: Wideband noise is injected into two legs of the bridge in equal quantities via a core transformer, T1. With the unknown impedance connected and the detector (your receiver) set to the desired frequency, R_p and C_p are adjusted for the deepest obtainable null. There is some interaction between the two adjustments, depending upon frequency, so that a readjustment between the two controls may be required to obtain the deepest null. When the null condition is achieved, the value of the unknown impedance is equal to the parallel combination of R_p and C_p. To permit measurement of both positive and negative values of parallel capacitance, the zero value of the C_p dial is set with the variable capacitor, C_p, approximately half-meshed. To balance the bridge with this offset, a fixed capacitor, C_f, is placed across the unknown terminal. This forces the bridge to balance with a purely resistive load when the half-meshed C_p is equal to C_f. However, by labeling the C_p dial zero at this point, the correct capacitance is registered by the instrument.

*Rms stands for root-mean-square which is a measure of dispersion. Mathematically it is equal to the square-root of the average or mean value of the squares for a series or data points. For random errors, usually about two-thirds of the errors will be smaller than the rms error.

Several advantages of the noise bridge concept now become apparent:

1. The frequency at which the measurement is being made is determined by the detector (your communications receiver), and this should be very accurate.

2. Measurement of inductive reactance does not require an accurate variable inductance which, in practice, is difficult to build.

3. Very little power is required from the noise source generator since the detector is quite sensitive.

On the negative side, you might expect some difficulty with this circuit for the following reasons:

1. The capacitance dial does not read out directly in ohms since this parameter is a function of the measurement frequency.

2. The resulting R_p and C_p values are parallel-circuit values, and series parameters are required in many practical applications.

3. A large amount of parallel capacitance is required to achieve balance with some modestly reactive impedances, particularly at low frequencies.

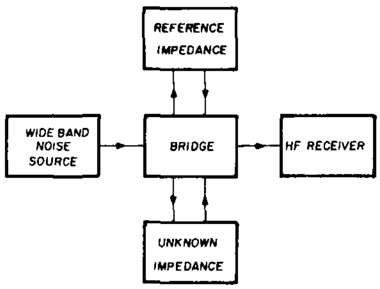


fig. 1. The noise bridge includes five major elements, three of which are internal to the instrument. The heart of the instrument is the bridge section itself. This is excited by a broad spectrum noise source. The unknown impedance and a reference impedance form separate legs of the bridge section. The reference impedance is varied until it equals the unknown impedance. When this occurs, the bridge is nulled and the output of the high-frequency receiver goes to a minimum.

Don't become overly discouraged over the negative aspects — we would like to add that none of these are of serious concern and, in fact, the first two reduce to simple calculations with a hand-held calculator. The third may be handled with the aid of a range extension assembly which we discuss in a later section. The required mathematical relationships will be covered in a section devoted to practical applications.

initial units

Our exposure and efforts on the practical noise bridge circuit had an innocent beginning when we built the noise bridge described by YA1GJM with the modification suggested by K2BT.[1,2] Initial experiences were delightful. Extremely deep and repeatable nulls could be obtained while measuring complex impedances. Actual use of the device on antenna measurements and adjustment of a transmatch were not, however, nearly as fruitful. Adjustment of a transmatch to obtain a measured 50-ohm resistive impedance with a 21-MHz antenna system did not coincide with the adjustments to

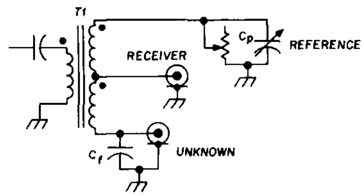


fig. 2. The bridge section of previously recommended noise bridge designs included a trifilar wound transformer. This injects wide spectrum noise approximately equally into the two halves of the secondary. When the parallel combination of the unknown impedance, shunted by a capacitor, C_f, is equal to the parallel combination of R_p and C_p, the bridge is balanced and the receiver detects a null condition.

achieve minimum swr meter readings. Similarly, we found that the familiar Heath dummy load did not appear to be close to the 50-ohm design value at the higher frequencies. Somewhat perplexed at this point, we fell back to consider the next step.

K2BT mentioned evidence of calibration shifts when using the device at higher frequencies and this seemed to be related to our experience. We also began to suspect that our knowledge of the impedance of carbon resistors which we had been using to evaluate performance of the bridge was not satisfactory.

We decided to explore the intrinsic performance of the noise bridge in a more rigorous manner. Fortunately, we have access to a Boonton Radio RX-Meter, model 250A. This is a highly respected, laboratory quality instrument which also measures the R-C parallel equivalent representation of an rf impedance. Test circuits were constructed of various resistances, capacitances, and/or inductance combined in parallel or series. These were measured first on the Boonton and next on a second noise bridge unit which we built with more care to shorten leads in the bridge circuit. The results are summarized in **table 1**.

These data were mostly concentrated at the higher frequencies (21 and 28 MHz) where problems, if encountered, were expected to be most pronounced. **Table 1** indicates some interesting consistencies as well as some interesting anomalies. The noise bridge nearly always indicated a more inductive (smaller) C_p than the RX Meter. The only exception was test circuit 1. Here the error was not only capacitive but also extremely large. There was also a tendency for the noise bridge to indicate a higher than correct value for R_p, particularly for higher values of load resistance.

It is interesting to compare these results with the words of K2BT.[2] He thought his unit exhibited an "inductive rotation" of the C_p calibration at the higher frequencies. That is a succinct way of summarizing our C_p data in **table 1**. Conversely, however, K2BT did not notice R_p errors at the higher frequencies. YA1GJM claimed that 2-watt composition resistors in the 10- to 150-ohm range exhibit "about −14 pF inductance in parallel with their indicated resistance values."[1] Test circuits 1 and 4 are composition resistors, number 1 being a 15-ohm value, and number 4 a 150-ohm value.

We find it very interesting that our noise bridge also indicated roughly this value of shunt inductance for these resistors. Note, however, that the readings are *incorrect*! In general, our findings indicate that composition resistors above 50 ohms exhibit relatively small values of shunt reactance. In fact, these are handy devices for use in calibrating the noise bridge as we shall explain later.

We were basically dissatisfied with the performance of this latest noise bridge. We think it is fair to say that our unit was probably as good as those made by either YA1GJM or K2BT. Indeed, as pointed out above, there appear to be significant correlations in the way our unit performed with the descriptions provided by these authors. Therefore, it seemed probable to us that some systematic errors were inherent to all these units. This prompted us to vigorously attack the problem of accuracy improvement.

improving accuracy

We could easily fill this entire issue of *ham radio* if we tried to relate, in any detail, all the avenues pursued in trying to improve noise bridge accuracy. A total of six different units were built with variations in each which we thought would be helpful. Many of our initial recipes for improving accuracy turned out to be blind alleys; others showed promise but did not provide the desired improvement. In the end we found four distinct design changes which definitely improve the performance of the instrument.

All of our improvements relate to the fundamental problem of achieving balance in the bridge section. Consider **fig. 2** which shows the previously recommended trifilar-wound transformer, T1. Clearly the desire is to balance both sides of the secondary circuit. Indeed, if the parallel combination of the unknown impedance and the fixed capacitor, C_f, is equal to the parallel combination of R_p and C_p, the secondary should be balanced. However, this will be true only so long as there are no additional coupling paths which affect secondary circuit balance. Unfortunately, the toroidal transformer couples energy between the primary and the secondary circuits *both* inductively and capacitively. Thus, if the primary circuit is unbalanced as it is in the trifilar configuration, then you can expect this capacitive coupling to slightly unbalance the secondary circuit as well.

To understand this point, imagine small fixed capacitors from the primary circuit to the secondary circuit.

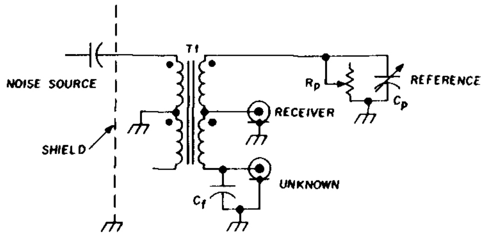


fig. 3. The recommended improved bridge section contains a quadrifilar wound transformer. This winding technique significantly reduces unbalanced capacitive coupling between the primary and secondary circuits. An electrostatic shield between the bridge and the amplifier electronics is also recommended.

Since the *dot* ends of each winding are physically near each other, then you expect the *reference* side of the secondary circuit to be most tightly coupled to the *ungrounded* side of the primary, whereas the *unknown* side would be more tightly coupled to the *grounded* part of the primary, circuit. It is not difficult to imagine rather significant unbalancing effects from this unbalanced capacitive coupling – particularly so at the higher frequencies.

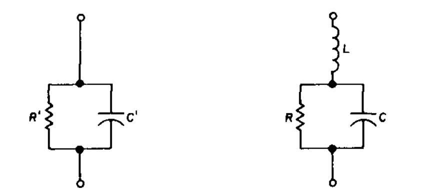
Fig. 3 schematically shows the recommended transformer configuration. The toroid is wound in a quadrifilar configuration. The additional winding serves to balance the primary to secondary circuit capacitive coupling. Note that one end of this primary circuit is left floating. To achieve the most perfect balance, it should be tied back to ground through an impedance equal to the driving impedance of the amplifier stage. However, from a practical standpoint, our results indicate no measurable improvement in trying to simulate this amplifier impedance with various terminations. Hence, we recommend leaving the other end floating as shown in **fig. 3**.

Note also that a grounded electrostatic shield is installed between the amplifier and the toroid. This serves the same purpose as above, reducing stray capacitive coupling to the secondary circuit. These are two of the four improvements we made, and in retrospect it is clear that the quadrifilar winding is the more important improvement.

Ground loops can easily exist in rf circuits. Unfortunately, they are difficult to diagnose and their effects on circuit performance are sometimes difficult to predict. We had observed strange behavior in several of our early noise bridge models which we now ascribe to this phenomenon. The mechanism is relatively simple. The chassis is necessarily part of the secondary circuit. It is also possible to have currents from the primary circuit return through the chassis; however, when this occurs, the primary and secondary circuits are again coupled in a way which may lead to unbalanced behavior. Rather than pre-empt the section which carefully details how to build our improved noise bridge, we will conclude discussion of this third recommended improvement by simply saying it is necessary to carefully ground the amplifier and bridge circuit components to achieve the best accuracy.

After making all three of the above noise bridge improvements, we were still noting some residual high-frequency unbalance. Our results, measuring carbon resistors in the 150-200 ohm range with the Boonton 250A, indicate that these resistors have very small equivalent parallel capacitance – usually 1 or 2 negative picofarads. Hence, as we shall see in the section on checkout and calibration, they are convenient standards for estimating noise bridge accuracy. At 3.5 MHz, measuring a 150-ohm resistor, the modified noise bridge would correctly indicate very small parallel capacitance, but at 28 MHz it could indicate nearly –10 pF and, furthermore, the indicated resistance value was higher than it should be. We soon discovered that by reversing the secondary winding of the quadrifilar transformer, the effect could be made to reverse. Hence, the error at 28 MHz would now be in the capacitive direction and the indicated resistance would be too low. This clue was sufficient to point us in the right direction.

Consider **fig. 4**. Suppose we have a parallel R-C circuit to which we add a very small series inductance. We wish to find the parallel $R'C'$ circuit which, at some particular frequency, has the same impedance as the circuit with the added series inductance. The algebra you have to grind through to get expressions for R' and C' in terms of *R, L, C, and frequency is a bit tedious. However, if* you are willing to make the approximation that the



$Z_0 = \frac{R'}{1 + j2\pi f R'C'}$ $\qquad$ $Z_1 = j2\pi f L + \frac{R}{1 + j2\pi f RC}$

$Z_0 \approx Z_1$ IF $R' = \frac{R}{1 + 8\pi^2 f^2 LC}$ AND $C' = C(1 + 4\pi^2 f^2 LC) - L/R^2$

fig. 4. A small amount of series inductance added to a circuit results in a shift in the R-C parallel representation of the impedance of that circuit. The shift in impedance can be represented by another parallel R′ - C′ circuit. Numerical values for the shifted resistance and capacitance are found from the equations in the text. These are approximate in that they assume the reactance of the series inductor to be smaller in magnitude than the reactance of either R or C.

reactance of the small inductor is much less than that of any of the other components, then a relatively simple result emerges:

$$R' \approx \frac{R}{1+8\pi^2 f^2 LC}$$

$$C' \approx C(1 + 4\pi^2 f^2 LC) - L/R^2$$

where f is frequency.

Now to the point of this whole discussion. Suppose you wished to measure the impedance of a 100-ohm resistor with your noise bridge. On the unknown side you would have the 100-ohm resistor in parallel with the fixed capacitor. For the moment, assume the fixed

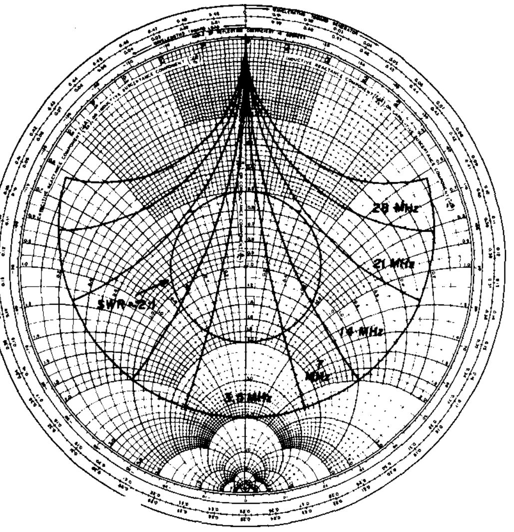


fig. 5. The range of impedance which can be measured using the basic noise bridge configured with a 365 pF variable capacitor and a 250-ohm potentiometer is shown in this diagram. Since capacitor reactance varies with frequency, the range of the bridge increases with increasing frequency as shown. The center of the Smith chart is 50 ohms and other impedances are scaled relative to this value. A 2:1 swr circle is shown on the chart for comparison.

capacitor to be 180 pF. Ideally, the bridge section would balance if you turned the pot and the variable capacitor on the reference side to these same values. Suppose, however, that one of these sides, either the reference or the unknown, had a small 10 nanohenry inductance in series with it. At 3.5 MHz, using the equations shown above, $R' = 99.8$ ohms and $C' = 179.2$ pF.

Hence, at this frequency, the very small series inductance causes a small but essentially immeasurable shift in bridge balance. However, at 28 MHz, using the same values as before, $R' = 90.0$ ohms and $C' = 189.0$ pF. Thus, the very small series inductance becomes a significant bridge unbalance at this frequency. If it exists on the known side, it causes the bridge to overestimate the resistance and to miss the correct capacitance on the inductive side. If it exists on the unknown side, the errors are reversed.

To put this in perspective, no. 28 (0.3mm) wire has an inductance of about 9 nanohenries/centimeter. In the process of winding a toroidal transformer and in wiring the bridge section it is not hard to imagine getting an extra centimeter of copper in one side of the bridge. Hence, our fourth and last suggested improvement is to achieve final bridge balance using a short piece of bare hook-up wire on the unknown side of the bridge to balance this effect. We will discuss this procedure in more detail in the section on checkout and calibration.

range extension

In terms of parallel equivalent circuits, the range of the noise bridge using a 250-ohm pot for R_p, a 365-pF variable for C_p, and 180 pF for C_f is roughly:

$$0 \leqslant R_p < 250 \ ohms$$

$$-180 \ pF \leqslant C_p < 180 \ pF$$

This representation, however, is not very informative. Instead, let's look at this range as a contour plot on a Smith chart. W1DTY discusses the use of these charts in the November, 1970, issue of *ham radio*, and this discussion assumes that you are familiar with using them.[3]

Since the reactance of a fixed capacitor is frequency dependent, we can expect the range of the bridge to also be a function of frequency. This is shown in **fig. 5**. In this presentation the center of the chart is 50 ohms. Five contours are shown; each represents the range of the noise bridge at the indicated frequency.

Suppose you wished to measure the impedance of an antenna at 3.5 MHz. Suppose further that the antenna swr at this frequency is 2:1. Therefore, its impedance is somewhere on the 2:1 swr circle on the Smith chart. Note, however, from **fig. 5** that only a very small portion of the possible impedances on a 2:1 swr circle are within the bridge's range at 3.5 MHz. K2BT noted this same problem, and recommended using a 365 pF variable instead of the 140 pF variable originally suggested by YA1GJM to increase the bridge's range. K2BT also suggested building the bridge so that fixed capacitance

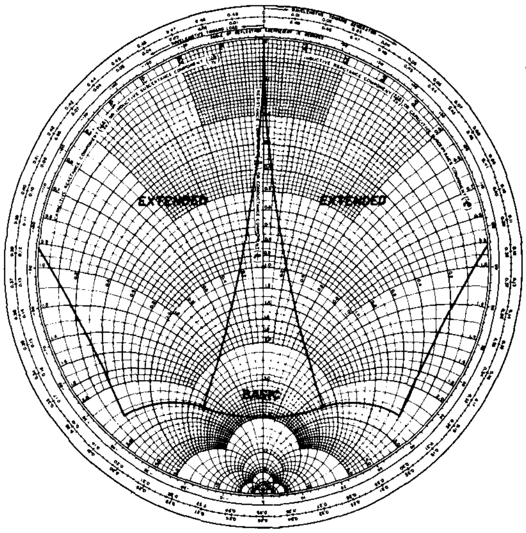


fig. 6. The range of the basic noise bridge can be greatly extended by adding a 100-ohm resistor in series with the unknown impedance. The extended range of impedances which can be measured using this technique is shown on this Smith chart. The center of the chart is 50 ohms, and the extended range includes all points on and within a 5:1 swr circle at 3.5 MHz.

could be added in parallel to either the reference or unknown sides of the bridge. We feel this is an excellent technique. Its only limitation is the required size of the fixed capacitance and possible construction difficulties. For instance, to measure any point on a 2:1 swr circle at 3.5 MHz requires the addition of up to 510 pF to the bridge. Extending the requirement to a 5:1 swr circle requires up to 2010 pF fixed capacitance.

An alternative which we feel is often more attractive is the addition of 100-ohm resistor in series with the unknown. In effect, this lowers the Q of the circuit to be *measured and brings the resultant within the range of* the bridge. The possible range extension at 3.5 MHz is shown graphically in **fig. 6**. This extended range includes all points on and within a 5:1 swr circle at 3.5 MHz and becomes even larger with increasing frequency.

A convenient range extender assembly will be described in the construction section; the mathematical formulas required to process the noise bridge readings with the 100-ohm range extender in place are included in the applications section.

results

So far we have stated that accuracy improvements to the noise bridge can be made with certain design changes. We have also alluded to a technique for extending its range. The last three sections of this article will describe in detail just how to accomplish these results. However, before we proceed with these detailed descriptions, it's logical (and motivational) to demonstrate our claims.

Table 1 summarized data taken on a noise bridge in accordance with earlier prescriptions. By way of comparison, **table 2** summarizes measurements made on these same terminations, but taken with two units built as described in this article. These are labeled, respectively, Unit 2 and Unit 3. Each of us built one of these, and other than the specific requirements imposed in the construction section, they are dissimilar. For purposes of comparison, the data from **table 1** (and Unit 1) are repeated.

Units 2 and 3 show a marked improvement in their correspondence to the Boonton measurements. The "inductive rotation" error evident in Unit 1 all but disappears in both these units. Further, the rather sizable error in measuring the C_p of the first load has disappeared. The only significant errors which remained in the Unit 2 and 3 data are on the last test circuit where errors of 12 and 17 pF, respectively, were made. But these are one-half the corresponding error in Unit 1. Also, any substantial indication of a systematic error in resistance measurements has disappeared. The rms error pretty well summarizes the data. Units 2 and 3 outperformed Unit 1 by a factor of more than three to one!

Although the results shown in **table 2** pretty clearly indicate an improvement in measurement accuracy for both Units 2 and 3, we felt that additional data was desirable to more fully explore the accuracy potential of the improved units. Using a number of different building blocks, including discrete resistors, capacitors, and inductors and, in several cases, short coaxial lines with resistive termination, we built a number of additional test loads. Our intention was that these loads should include both inductive and capacitive reactance and both small and large values of resistance. They were synthesized to be roughly arranged around the 3:1-swr circle on a Smith chart with $Z_o = 50$ ohms. Some of

table 1. A noise bridge unit built according to previously described articles as compared to a Boonton 250A RX meter.

MEASURED IMPEDANCE PARAMETERS

test circuit number	freq. MHz	Boonton R_p	Boonton C_p	noise bridge R_p	noise bridge C_p	error relative to Boonton ΔR_p	error relative to Boonton ΔC_p
1	7.2	15.5	−156	17	−18	1.5	138
2	28.2	138	−62	160	−65	22	−3
3	21.2	162	−43	162	−52	0	−9
4	28.2	149	−1	160	−15	11	−14
5	14.2	141	59	145	45	4	−14
6	21.2	37.5	182	35	150	−2.5	−32

table 2. Improved noise bridge units 2 and 3 as compared with unmodified unit 1 and the Boonton RX meter.

MEASURED IMPEDANCE PARAMETERS

test circuit number	freq. MHz	Boonton R_p	Boonton C_p	Unit 1 R_p	Unit 1 C_p	Unit 2 R_p	Unit 2 C_p	Unit 3 R_p	Unit 3 C_p
1	7.2	15.5	−156	17	−18	14	−160	16	−160
2	28.2	138	−62	160	−65	142	−55	140	−56
3	21.2	162	−43	162	−52	161	−41	160	−40
4	28.2	149	−1	160	−15	150	−4	147	−1
5	14.2	141	59	145	45	142	60	136	58
6	21.2	37.5	182	35	150	35	165	34	170
rms measurement error relative to the Boonton				10.2	58.5	2.1	7.8	2.9	5.9

table 3. Improved noise bridge units 2 and 3 as compared with the Boonton RX Meter for a number of representative test circuits. All recorded data was converted to series impedance and therefore the entries have units of ohms.

test circuit number	freq. MHz	100-ohm resistor used	*measured impedance* Boonton	Unit 2	Unit 3
1	7.2	no	15 + j2	14 + j1	16 + j2
2	14.2	yes	19 + j48	22 + j49	19 + j49
3	28.2	no	42 + j63	49 + j67	48 + j66
4	21.2	no	86 + j81	91 + j80	93 + j79
5	28.2	no	149 + j6	148 + j16	147 + j4
6	14.2	no	91 − j67	90 − j67	91 − j63
7	3.7	yes	51 − j45	52 − j44	51 − j44
8	21.2	no	21 − j19	22 − j17	21 − j17
9	3.5	yes	17 + j16	20 + j17	18 + j15
10	7.0	yes	23 + j34	28 + j35	27 + j32
11	14.0	no	120 + j61	122 + j58	123 + j54
12	21.0	no	55 − j59	54 − j61	54 − j58
13	28.0	no	21 − j16	21 − j17	19 − j13
14	3.5	yes	85 − j67	81 − j66	80 − j66
15	7.0	yes	39 − j51	38 − j53	38 − j49
16	14.0	yes	19 − j14	17 − j13	19 − j14
17	21.0	yes	20 + j14	22 + j12	20 + j16
18	28.0	no	43 + j47	48 + j49	46 + j52
rms measurement error relative to the Boonton				ΔR = 3.2 ohms ΔX = j2.9 ohms	ΔR = 3.0 ohms ΔX = j2.8 ohms

fig. 7. Interior layout of the improved noise bridge is shown in this photograph. A copper electrostatic shield encloses the bridge section. The three leads from the bridge section can be seen at the upper right-hand corner of the perf board. One is a ground lead and the other two are leads from the primary of the toroid. One primary lead is connected to the amplifier output; the other is left unattached as explained in the text.

these impedances are clearly outside the range of the noise bridge in its usual configuration. In these cases, the 100-ohm resistor technique briefly described above is required to obtain a measurement.

Table 3 shows the results of measuring these new test loads on Units 2 and 3. In all cases, the measurements were converted into the series circuit equivalent of the measured impedance. As before, the data are compared with those taken on the Boonton 250A RX-Meter. For convenience, these data were also converted to series equivalent.

There are several ways of describing the accuracy of these measurements. The rms error for each unit was about 3 ohms in both the resistive and reactive components. Considering the distribution of errors, one is 10 ohms, several are in the 5 to 7 ohm range, but *nearly half are 1 ohm or less*! While we shall purposely avoid making a global statement about the accuracy of these units, the data is encouraging well beyond our original hopes. Many high-quality instruments have accuracy expressions relating to "percent of full-scale reading;" our noise bridges appear to be in the "few" per cent category.

constructon

Figs. 7 and **8** shows the details of construction we recommend. The 2¼ by 2¼ by 5-inch (5.7x5.7x12.7cm) box allows easy construction as well as a component arrangement which minimizes lead length. A conventional 365-pF air-dielectric variable can be made to fit in this same box, although it is recommended that the more compact Archer 272-1341 capacitor be used to improve access to the actual bridge circuit wiring during calibration. The amplifier circuit, **fig. 9**, was built on a small piece of perf board in the model pictured although two other units we built used a printed-circuit board. Both construction techniques resulted in identical performance and the circuit itself is immune to layout variations. The potentiometer should be a linear taper, carbon variety such as an Allen-Bradley, type J. Wirewound pots are unacceptable because of their high inductance.

Shielding is arranged so that the battery, electronics, and on/off switch are external to the critical bridge circuit components. Copper sheeting was formed so that one end is secured under the variable resistor and the sides are clamped between the flange of the chassis-mount coax connectors and the box. The electronics board was then mounted with a single screw and spacer on the major surface of the copper shield.

Short leads are important in the bridge circuit area with the exception of the leads going through a single hole in the shield near the output end of the electronics board. Of particular importance is the detail involved with grounding. The ground lug of the variable capacitor is used as the focus of a single-point grounding system; an insulated ground wire is routed from this point to the electronics along with both ungrounded primary leads from the toroidal transformer. Both ends of the primary

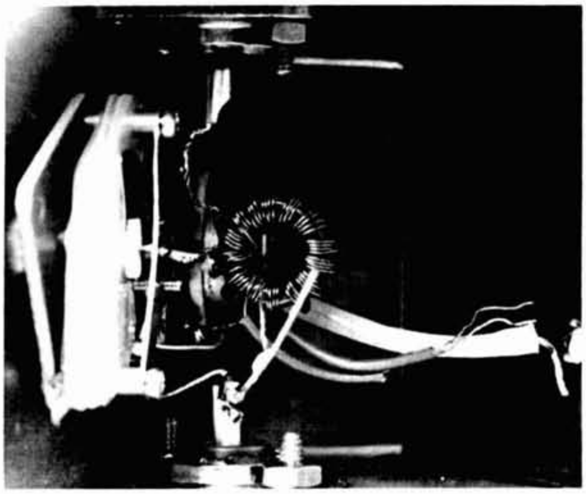


fig. 8. This closeup photograph of the bridge section shows the location of major components. The small 365 pF variable is on the left while the 250-ohm pot is in the background behind the toroid. The SO-239 coaxial connectors are on either side of the box between the capacitor and resistor, providing a compact layout. The leads to the amplifier ground and from the toroid primary, as well as the hole through the copper shield to accomodate them, are in the lower right. The series inductance balancing device can be seen emanating from SO-239 connector on the bottom.

windings will be required during the calibration sequence. Overall construction of the noise bridge is shown in **figs. 7** and **8**, and retention of this component layout is encouraged.

Construction of the 100-ohm range extender is quite simple with the use of a PL259-to-Motorola type pin plug (Archer 278-208). This unit fits conveniently into the back of a PL-259 plug (Archer 278-205). The adapter plug must be modified to allow for series connection of the 100-ohm, ½-watt carbon resistor. All but ¼ inch (6.5mm) of the Motorola plug is cut off, including the center pin. The 100-ohm resistor is soldered to the shortened inner pin and the assembly is then inserted into the PL-259 plug.

Several spots can be soldered to secure the two units together and the resistor lead projecting out of the PL-259 plug may then be soldered. The layout of the assembly is shown in **fig. 10**; the completed unit is pictured in **fig. 11**. It might be tempting to consider installing the 100-ohm range extender inside the noise bridge with a switch to more easily select its use. This was tried, with mixed results, so we recommend you use the external device if comparable accuracy is desired.

checkout and calibration

Initial checkout of the noise bridge can be accomplished by connecting the unit to your receiver and leaving the unknown coax connector unterminated. There should be generous amounts of noise anywhere between 3.5 and 30 MHz! Although the output falls off somewhat at the higher frequencies, an S-9 signal should be expected on 10 meters. No null can be expected under these conditions. By varying the R and C dials, however, some variation in the S-meter reading is normal. Failure to observe these results requires checks of wiring and measurement of bias levels on the zener and transistor terminals. Access to an oscilloscope is helpful for signal tracing, but it was our experience that voltmeter measurements are quite satisfactory.

The next step in the checkout is to see if nulls can be achieved and that the bridge circuit is basically working. Connect the range extender assembly to the *unknown* coax connector and short the output of the 100-ohm resistor to ground through a physically short connection. By placing the receiver on 80 meters with a short agc time constant, if available, it should now be possible to find an extremely sharp null on the S-meter by adjusting both the R_p and C_p dials. Since there will be some interaction between the adjustments of the dials, the sequence must be repeated until the minimum S-meter reading is obtained. This null should be all but absolute, that is, near zero on the S-meter.

Since the unknown being tested is near 100 ohms with little reactance, the resistance dial, which is linear, should read approximately 40 per cent of scale from the zero position, and the capacitance dial would be expected to read near the center of its range. Inability to obtain these results indicates a problem in the bridge circuit and transformer connections should be checked.

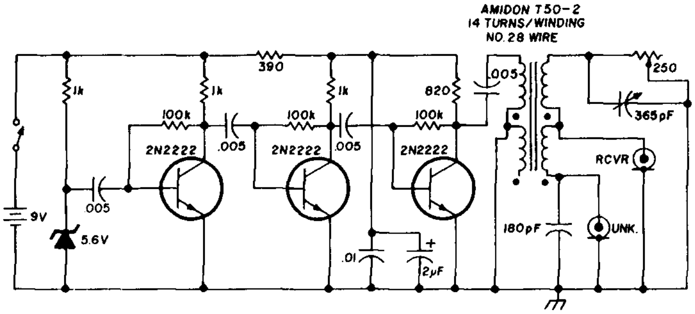


fig. 9. Schematic diagram for the improved noise bridge unit. Construction details are discussed in the text.

Offset of the capacitance dial from approximate center would indicate difficulty with the 180 pF fixed capacitor.

Assuming a successful checkout, you can now proceed with calibration. Preparation includes lightly steel-wooling the paint under the R and C dials to remove the gloss and permit the use of India ink or a fountain pen for scale markings. Later, a clear alcohol-based artist-type aerosol spray can be applied to protect the markings and make them more durable. Some clear sprays interact with ink, so a preliminary try is advised to avoid an upsetting experience after you have finished the calibration sequence.

With both the receiver and unknown disconnected, the resistance dial can be calibrated by attaching an accurate ohmmeter to either coax connector and ground. Surprisingly, dc resistance readings and accompanying marks on the resistance scale are very accurate from 80 through 10 meters. Tick marks every 10 ohms are a good balance between readability and scale appearance. Lacking an accurate ohmmeter, it might be advisable to locate several 1 per cent resistors in the 10 to 250 ohm range for reference.

Calibration of the capacitance dial is most easily accomplished with a capacitance meter. The variable capacitor must be temporarily disconnected from the rest of the bridge. Establishing the 180 pF dial setting as zero, the scale can then be marked in both directions to an "end-of-scale" reading of approximately 180 pF in either direction. Tick marks every 10 pF are desirable; the most clockwise 180 pF value should be marked with an L to indicate that inductive reactance is in that direction.

Lacking access to a capacitance meter, calibration of the C dial requires the following sequence: Connect the noise bridge to your receiver and select the 80-meter band. A 100-ohm, ½-watt carbon resistor and a selection of accurate capacitors in the 10 to 180 pF range should be at hand. Start with the 100-ohm resistor only and attach it to the unknown coax connector with short leads. Establish a null by observing the receiver S-meter and adjusting both the R and C dials. The resulting position of the C dial can then be marked as zero. By adding small values of capacitance in parallel with the

100-ohm resistor and rebalancing the bridge each time, the dial can be marked progressively until the 180 pF value is reached.

The next step is to temporarily remove the 180 pF fixed capacitor inside the noise bridge. Returning to the 100-ohm resistor measurement at 80 meters, capacitance should be added in parallel until the C dial reads zero as marked in the earlier step (approximately 180 pF will be required). Small values of capacitance should then be removed from the 100-ohm resistor until the scale has been marked as desired. Since the C scale is quite linear, some liberties may be taken in the form of estimating intermediate scale markings as long as accurate capacitors are used during the calibration process.

Following the scale marking sequence, all circuits can be returned to their original state in readiness for compensation adjustments which will assure accurate performance over the 3.5 to 30-MHz frequency. A 150-ohm, ½-watt carbon resistor should be placed on the unknown coax connector with short leads. The noise bridge may then be nulled on 3.5 MHz; both the resistance and capacitance dial should read fairly accurately at this point (150 ohms, 0 pF). Possibly the C dial might read slightly off zero at this time and the knob can be moved on the capacitor shaft to correct this situation. Moving your receiver to 30 MHz, again measure the 150-ohm resistor. If you get the same readings as you did at 3.5 MHz, the effort is over and you have a good instrument!

More than likely you will see a small shift at 30 MHz. If the R_p dial reads higher, and the C_p dial reads on the inductive side of zero, then your bridge needs additional series inductance on the unknown side. We recommend that you solder a short piece (about 1 inch or 25mm) of bare hookup wire to the SO-239 coaxial connector

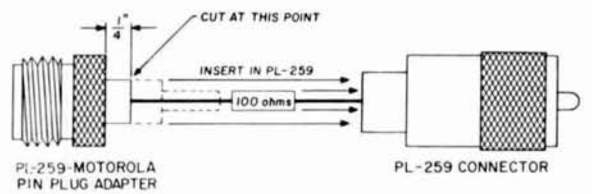


fig. 10. Construction details for the 100-ohm range extender unit. A PL-259 to Motorola pin plus adapter is first prepared by cutting off all but ¼" (6.5mm) of the pin and shank. A ½ watt, 100-ohm resistor is then inserted in the pin of this adapter and soldered. The shortened shank and resistor are then inserted in the back of the PL-259 plug. The other resistor wire is soldered to the center pin of the PL-259 connector. Soldering the exterior surfaces together completes the assembly.

marked *unknown*. The fixed C_f, 180 pF capacitor should remain soldered at this connector with a short lead to ground. The wire from the transformer secondary should be removed from the SO-239 connector and fastened instead to the 1 inch (25mm) piece of wire. Connect it to the far end of this wire and rerun you balance test.

You should now find that your error at 30 MHz has reversed (instead of R_p reading too high, it will now be too low). In addition, the C_p reading should be on the capacitive side of zero. If this is the case, move the wire from the transformer a little closer to the SO-239

fig. 11. The completed range extension assembly.

connector along the 1 inch (25mm) wire and rerun your test. You should find a point where the R_p and the C_p dials read very nearly the same at 30 MHz as they did at 3.5 MHz. When they do, your work is complete.

Suppose, instead of R_p too high and C_p inductive at 30 MHz, your first measurement (without the 1 inch or 25mm wire) indicates the opposite. This means that your bridge has too much inductance on the unknown side. In this case, instead of trying to add wire to the known side it is easier to reverse the transformer primary windings to shift the error in the other direction. Then you can proceed to finish the calibration as discussed above.

Suppose you find a high-frequency shift that is different from those discussed above. Perhaps R_p increases and C_p also increases (goes capacitive). If this is the case, it indicates your unbalance is more than just a problem of unbalanced series inductance and you should check your layout, particularly the winding and placement of your transformer. Try and make this layout as clean as possible. Make sure your shielding is effective and that a chassis ground loop does not exist. If all this is done properly, the residual unbalance should be such that it can be compensated with the series inductance technique.

applications

There are a number of applications in the shack which are ideally suited for the noise bridge. The first and most obvious is to use it to measure antenna impedance. Since the measurements will be made with the noise bridge located near the receiver, you will want to transform the values measured to those that apply to the antenna's feedpoint. Again, the Smith chart is recommended and W1DTY's article or the latest issue of the ARRL *Antenna Handbook* discusses the technique in detail.[3,4] An example of the results that might be obtained are shown in **table 4** and **fig. 12**. These data are from an actual 80-meter inverted-vee antenna with isolation traps resonant on 40 meters. It is fed with 60 feet (18.3m) of RG-8/U coaxial cable.

The actual mathematical steps involved in noise bridge impedance measurements are quite easy and relatively fast once the pattern is established. First, record the bridge readings; then compute the reactance of the parallel capacitor. The parallel circuit elements are then converted to series equivalent elements. These transformations are performed using the following equations:

$$X_p = \frac{-159{,}000}{fC_p}$$

where f = frequency in MHz
C_p = capacitance in pF

For the 4.0-MHz data point,

$$X_p = \frac{-159{,}000}{4.0(-84)} = 473 \text{ ohms}$$

Converting to series equivalent values required use of the following equations:

$$R_s = R_p \frac{X_p^2}{R_p^2 + X_p^2} \qquad X_s = X_p \frac{R_p^2}{R_p^2 + X_p^2}$$

Substituting 4.0 MHz values of R_p and X_p,

$$R_s = 117 \frac{(473)^2}{(117)^2 + (473)^2} = 110 \text{ ohms}$$

$$X_s = 473 \frac{(117)^2}{(117)^2 + (473)^2} = 27 \text{ ohms}$$

If the range extender was used, then actual values of the 100-ohm resistor must be subtracted from R_s before it is entered in the corrected series impedance column.*

At this point, the equivalent series representation may be plotted on a Smith chart, making allowance for the rotation required due to the electrical length of the transmission line used. The electrical length is easily established by using the velocity factor (v) for the coax in use (66 per cent for RG-8/U) and the following relationship

table 4. The noise bridge measured impedance of an actual 80-meter inverted vee antenna. Starting with the recorded values of R_p and C_p, the data are converted to equivalent series impedance, and finally "rotated" through the 60-foot (18.3m) length of RG-8/U used to feed the antenna. The final column tabulates the measured impedance of the antenna at its feedpoint.

frequency MHz	noise bridge recorded data		calculated capacitor reactance	series impedance		100-ohm resistor used	corrected series impedance		transmission line length	antenna impedance	
	R_p	C_p	X_p	R_s	X_s		R_s	X_s		R_s	X_s
3.50	149	−163	279	116	62	yes	16	62	0.323λ	30	−95
3.55	164	−163	275	121	72	yes	21	72	0.328λ	27	−85
3.60	202	−141	313	143	92	yes	43	92	0.333λ	25	−65
3.65	240	−98	445	186	100	yes	86	100	0.337λ	24	−50
3.70	129	−66	651	124	25	no	124	25	0.342λ	26	−31
3.75	78	152	−279	72	−20	no	72	−20	0.346λ	33	−9
3.80	144	20	−2092	143	−10	yes	43	−10	0.351λ	41	9
3.85	121	−9	4589	121	3	yes	21	3	0.356λ	48	45
3.90	118	−39	1045	117	13	yes	17	13	0.360λ	65	70
3.95	116	−65	619	112	21	yes	12	21	0.365λ	75	105
4.00	117	−84	473	110	27	yes	10	27	0.370λ	95	140

$$\lambda = \frac{\ell f}{984v} \text{ wavelengths}$$

where ℓ = physical length of coax in feet
f = frequency in MHz

For 4.0 MHz

$$\lambda = \frac{(60)(4.0)}{984(.66)} = 0.370 \text{ wavelength}$$

The equivalent series impedance components must, of course, be normalized to the Z_o value (division by 50 in this case) prior to plotting on the Smith chart. Construction details for the 4.0 MHz data point are shown in **fig. 12**. Although the influence of feedline loss could have been included, the degradation is small on 80 meters and, therefore, was ignored. The final results as presented by **fig. 12** allow considerable insight into the workings of this antenna:

1. Resonant frequency is 3.78 MHz.
2. Feedpoint impedance at resonance is 37 ohms.
3. Bandwidth with swr ⩽ 2:1 is 100 kHz.
4. Bandwidth with swr ⩽ 3:1 is 200 kHz.

With an antenna such as this one, you should not expect to load your transmitter at the band edge with-

*You should measure the actual value of your 100-ohm resistor by shorting the output end of the range extender and nulling your noise bridge.

out causing some sparks in your final tank circuit! A transmatch must be used to make the transmitter happy. Then there is the problem of properly tuning the transmatch at the frequency of interest. A good way to do this is to place the noise bridge at the transmatch input terminal and set the dials to $R_p = 50$ ohms and $C_p = 0$. Then by turning the transmatch dials, look for a null.

If a null can be found, the resulting swr at the transmitter will be very close to 1:1. And the best part is that you've done this without radiating any power and causing interference. It's a good idea to log these results for future reference. Be cautious, however, with this test setup, because it's possible, by hitting the wrong switches, to apply power to the antenna through the noise bridge. If you do this, even for an instant, you'll be in the market for a new 250-ohm pot and perhaps a new transistor in the amplifier circuit.

The particular antenna discussed earlier did not have a balun installed at the time these measurements were taken. In trying to find a suitable core to wind a balun, we discovered another application for the noise bridge. A core of appropriate dimensions but uncertain ancestry was available. In practice the resulting balun transformer didn't work. To discover why, a 50-ohm carbon resistor was soldered across the secondary of the balum and the input impedance measured with the noise bridge. With a good 1:1 balun we would expect to see an R_p of approximately 50 ohms in parallel with a negative C_p representing the reactance of the primary of the transformer. If this parallel reactance is large with respect to 50 ohms, the transformer works as it should. In this case we found a very high impedance primary circuit, beyond the range of the bridge. This indicated that the core material was not designed for the frequency range desired so a different core had to be obtained.

Another pet application involves power meters. We have built several of these and have wondered about their accuracy. If you have both a 50-ohm dummy load and a transmatch, you can use the noise bridge to synthesize arbitrary transmitter loads of interest. Unless you spent a lot of money for your dummy load, it probably is not exactly 50 ohms at any frequency. If you used it to set the null on your power meter, that null will not be the best that can be obtained. By using the transmatch/dummy load combination, you can synthesize an accurate 50-ohm impedance.

In addition, do you have confidence that when your power meter indicates a 2:1 swr that this is in fact the case? With the above hardware, you can synthesize an rf impedance of either 100 ohms or 25 ohms. Both should yield an swr of 2:1 on a 50-ohm coaxial cable. You might try this to see if your power meter indicates the correct values.

The last application we shall discuss effectively demonstrates the extreme range capability of the instrument when using the 100-ohm resistor modification. It is often desired to know the inductance of an rf coil. With air-core coils having uniform dimensions, it is possible to accurately compute inductance using

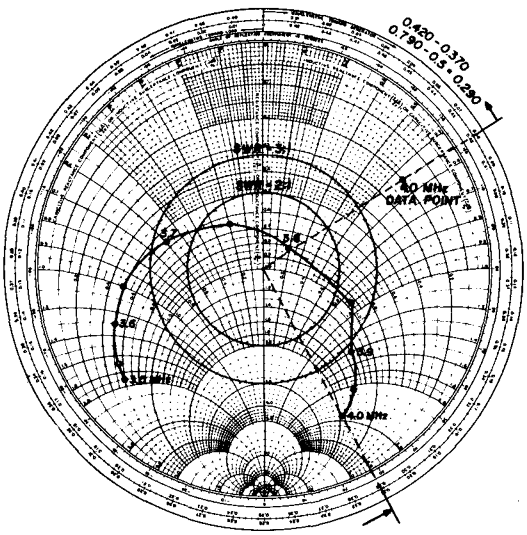


fig. 12. Smith chart plot of the noise bridge measured impedance of an actual 80-meter inverted vee antenna. The construction of the 4.0 MHz data point is shown for illustration. The measured impedance at 4.0 MHz must be rotated 0.370 wavelength "toward the load" to account for the 60′ (18.3m) RG-8/U transmission line. 2:1 and 3:1 swr circles illustrate the bandwidth of the antenna. The bandwidth is relatively narrow since the antenna is physically short (about 100′ or 30m long) and relies on the inductive loading effect of 40-meter traps to achieve resonance on 80 meters.

standard formulas. These formulas are much less precise and are more difficult to apply to inductors wound on a core such as a toroid. However, using the rf noise bridge, it is very easy to directly measure inductance in the "few" microhenry range.

By nulling the noise bridge with the 100-ohm resistor in the circuit and the unknown coil attached, observe the R_p and C_p readings. If a reading is not possible, try a lower frequency. The C_p reading should be negative, of course, indicating the inductive reactance of the load. The inductance of the unknown coil in microhenries is calculated by

$$L = \frac{-R_p C_p}{10{,}000} \ \mu H$$

We leave it as an exercise to mathematically inclined and interested readers to derive this equation. Most, I'm sure, would prefer to prove it by demonstration with a real rf coil. We earnestly invite you to build the rf noise bridge as described here so you can perform the demonstration yourselves!

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milliwatt portable counter

A low-power frequency counter using RCA COS/MOS ICs that operates to 4 MHz and above

How would you like to have a truly portable milli-powered frequency counter that is usable to over 4 MHz? The RCA line of COS/MOS digital logic integrated circuits makes it possible to build such a counter with a total power consumption of 300 milliwatts (12 volts at about 25 milliamps including current to light a seven-digit display).

features

With no circuit changes, such a counter can be run at any loosely regulated voltage between 4 and 15 volts with no loss of accuracy. It's possible to operate the counter from a common 9-volt transistor battery, a 12-volt automobile battery, or rechargable nickel-cadmium batteries. Obviously, line-power operation is possible by using a 6-volt transformer with a rectifier and filter.

The portability feature of this counter allows it to be used in hard-to-reach places in the same way that a hand-held vom is sometimes more useful than an ac-operated bench-type vtvm.

Although the frequency range of the counter is stated as "over 4 MHz" (to comply with published specifications on COS/MOS ICs), the model constructed actually works to 6.2 MHz. If a higher frequency range is desired, a single TTL divide-by-ten prescaler will increase the frequency to 50 MHz, which is more than adequate for most applications.

In designing this very low-power counter, it was decided to follow a nonconventional course of logic. This approach gives some insight into the use of a random-access memory, bus registers, and multiplexing.

A copy of the printed circuit board layout can be obtained by sending a self-addressed stamped envelope to *ham radio*, Greenville, New Hampshire, 03048

*In this circuit, two digits are lit at once as explained later.

This last item, multiplexing, is of interest because it provides a great reduction in digit current. Each digit is illuminated only 10 to 20 percent of the time. In other words, each digit operates on a 10-percent duty cycle and is off more than on. To the eye, of course, it appears to be continuously on. The peak current is higher than the normal continuous current, but because of the human eye, the average current can be less for the same apparent brightness. In addition, only one digit is lit at any given time.* Also the use of multiplex reduces the number of wires between the circuit board and the digits themselves. This makes is easy to mount the circuit board near the frequency source to be measured while the digits are placed where they are most convenient to read.

conventional counter

Fig. 1 shows the block diagram for a conventional frequency counter. Each divide-by-ten IC has a BCD output, which is stored in a latch, decoded, and displayed. While the dividers are counting, the information in the latches keeps the digits lit with the previous data. Periodically the new data is fed into the latches and the digits show the new values. All digits are lit at all times.

In a multiplex system, the decoder outputs are tied physically to a common set of bus lines. At clocked intervals, each decoder becomes electrically connected to the buses and its data is fed to all the LEDs. However, at the same time, only one digit corresponding to the *on* data is allowed to light through its common emitter and an external transistor that is clocked in synchronism with the data. Thus multiplexing is ideal for remote readout of data collected elsewhere. Most decoder outputs are two-state; that is, either high or low. With several outputs tied together, a conflict of decisions is continuously occurring on the common bus lines. To separate the data, it is necessary to put a diode in each output line to isolate it except when its data is desired. For seven digits, each with seven segments, 49 diodes are needed.

improved system

To overcome this disadvantage, while being able to reduce the number of wires by 65 percent, a different system was developed, still using RCA COS/MOS devices for low-power consumption. **Fig. 2** is a block diagram of this system.

The circuit difference lies in the manner in which data is combined, multiplexed into memory, then separated into two multiplexed outputs. One output is for the 3 least-significant figures and the other for the 4

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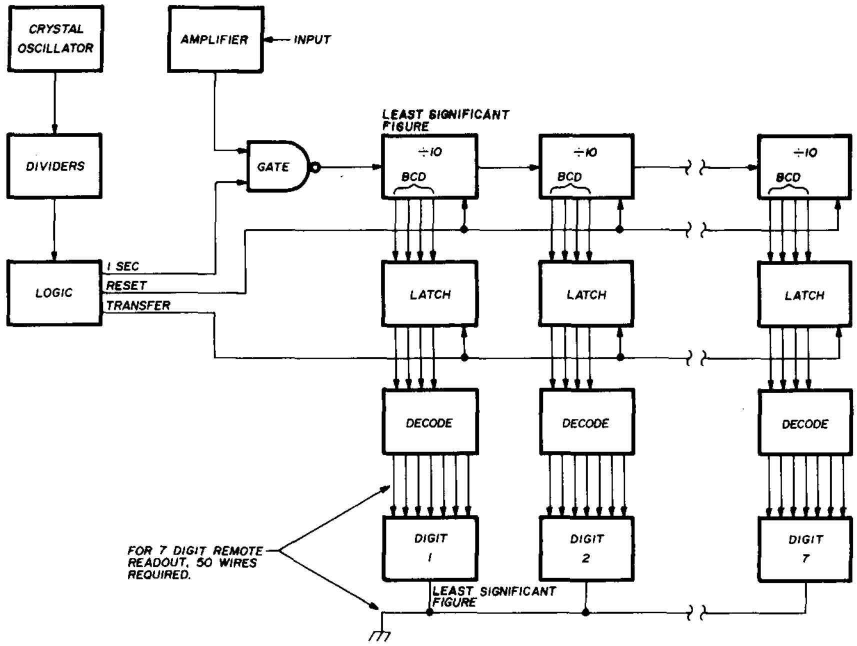

fig. 1. Block diagram of a conventional counter. Fifty wires are required between decoders and digital readouts.

most-significant figures. Use **fig. 2** or **3** to follow the explanation.

A 10-kHz crystal oscillator is used as the standard clock. The dividers and logic gates, U14 through U19 and half of U5, are used in conventional circuitry to provide the one-second count time as well as reset and write pulses. Note, however, that U15, an RCA CD4017A, has parallel as well as serial outputs. At any

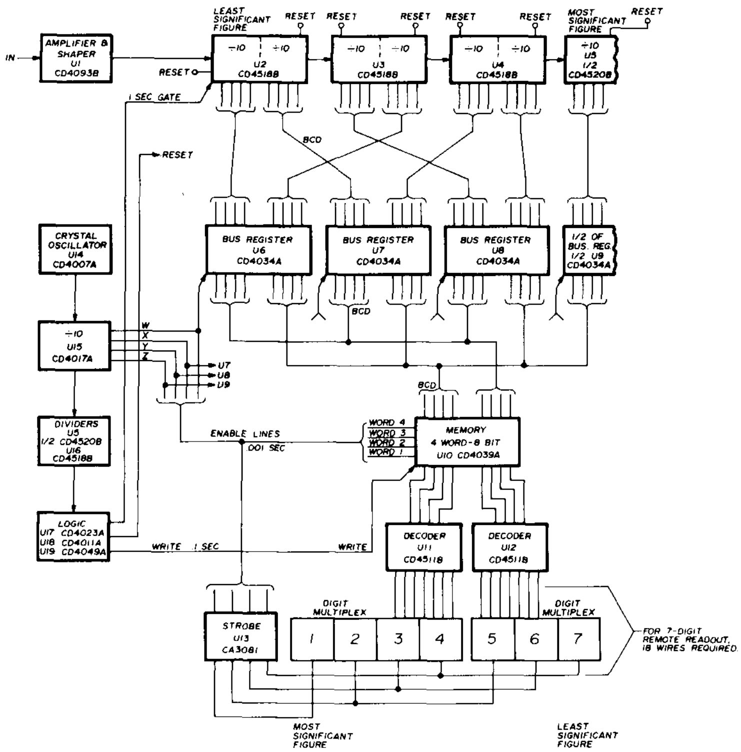

fig. 2. Block diagram of improved counter. Only 18 wires are required from the decoders to a 7-digit remote readout display.

time one of the 10 parallel output pins will be high. Each input pulse will move the high output in continuous sequence from zero to nine and back to zero. Each of these output pins will go high for every tenth pulse, but only one will be high at any given time. These pulses are the source of the clock timing for the bus registers, memory location and digit *on* time.

Assume the counters are counting. The changing BCD data in each counter also appears at the input to their respective bus registers, which are inactive until they are turned on. Each bus register has its own *enable* line tied to a different parallel output line of the CD4017A. One at a time, each bus register is activated, and the counter data is fed to the 8-bus multiplexer.

The memory, U10, an RCA CD4039A, has storage capacity for 4 words of 8 bits each. The memory sees this continuous changing flood of data on its input lines, but ignores it until it receives a *write* pulse from the control logic. This pulse occurs only after the counters have finished their one-second count and are in standby with the final count data. The location in memory for each data set is then chosen by a pulse that selects the word-enable lines, one at a time in synchronism with the data being fed to the bus lines. For one word, this data is the same pulse that enables bus-register one, U6. Therefore, word one becomes memory storage for the data from register one. The enable pulse then moves to bus register two, U7, and word two is enabled. The same action occurs with words three and four. This circuit has now multiplexed the counter data into memory.

Now let's notice the choice of data being fed to each memory word. The counter outputs are BCD and are therefore 4 bits long. Since each bus register can handle 8 bits and each word is also 8 bits long, the data from two counters can be fed simultaneously to each memory word.

The pairs chosen are not consecutive but are a

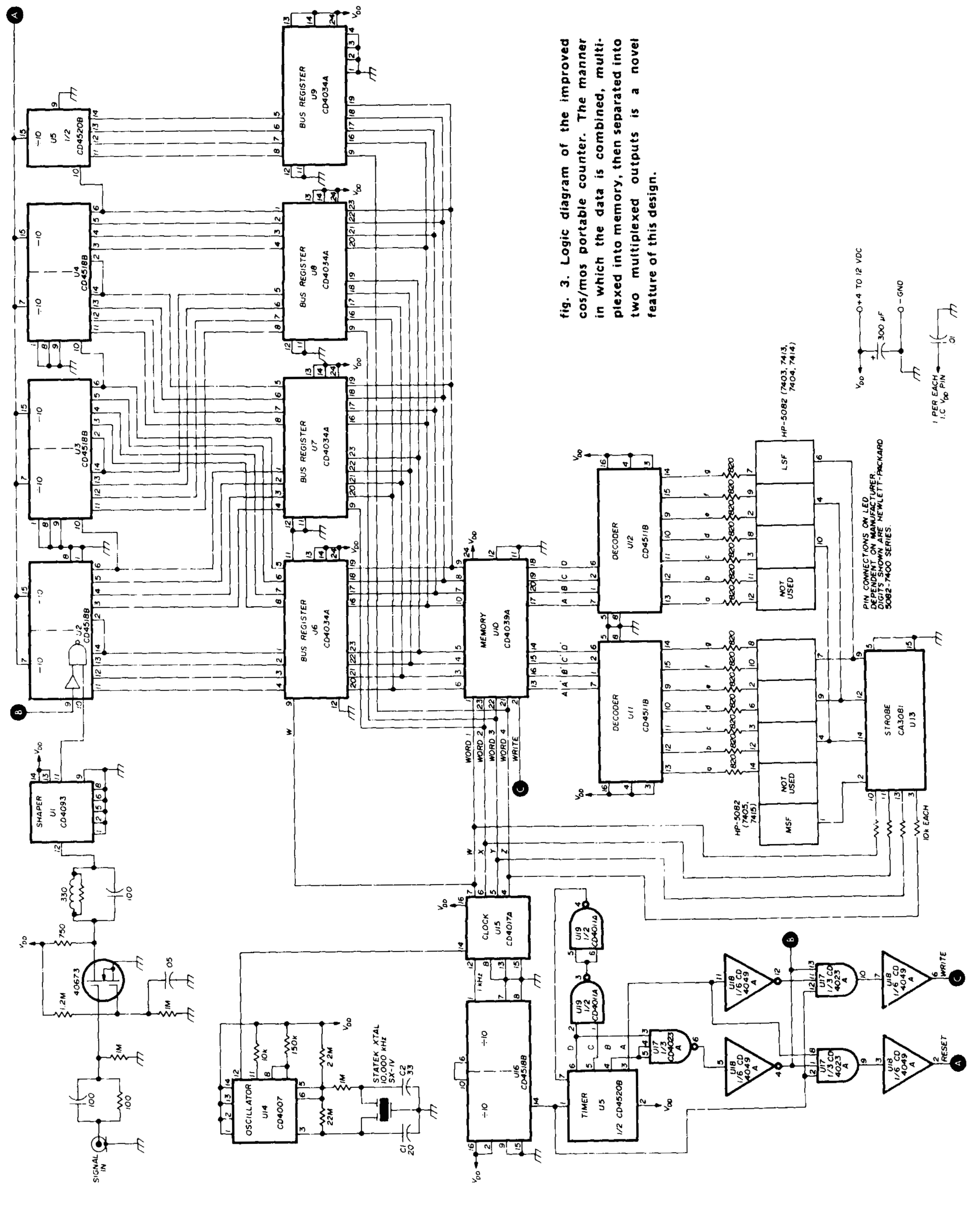

fig. 3. Logic diagram of the improved cos/mos portable counter. The manner in which the data is combined, multiplexed into memory, then separated into two multiplexed outputs is a novel feature of this design.

combination of digit one with four, two with five, and three with six; digit seven operates alone. The reason for this becomes evident when we see how the data is read from memory and separated.

Because the memory words each contain 8 bits (two BCD sets), two 4-bit decoders are necessary. One will receive the 3 least-significant figures and the other the 4 most-significant figures. The data is fed from memory by the same pulse that chooses the word to receive data. However, the reading ability is continuous while writing can occur only when the write line enables it. Thus the latest final-count data in memory is continuously being circulated to the output lines: first word one, then two, and so on. At any instant only one word appears at the output. As each word appears it is decoded by the two RCA CD4511 ICs U11 and U12. The first four bits go to one decoder; the last four to the other.

In a multiplex readout, the a segment of each digit is tied to a common line, each **b** to another line, and so on. The choice of the digit that is lit is made through the cathode of each digit. Thus digits 1, 2, and 3 have common segment lines. Digits 4, 5, 6, and 7 have a separate set of common segment lines. One of the decoders just mentioned goes to one multiplex set and the other to the second multiplex set. This is possible because the data being handled is from dividers one and four, U2 and U3. Had the data been from consecutive dividers (say one and two), the decoder outputs would have to feed data to the same line at the same time. As shown earlier this is not possible.

After word one is read and transferred to the digits, word two is read and data two and five are sent to the digits. Words three and four then follow in sequence. Since all three (or four) digits on a common set of lines receive the same data that was meant for only one digit, it is necessary to strobe each digit in time with its proper data. This means that the clock pulse that allows word one to be read must also turn on the correct pair of digits corresponding to this data. This is done by transistor, U13, an RCA-CA3081 connected to the cathode lines of each pair. The transistor is turned on by the same clock pulse that allows word one to be read.

The strobe rate is not critical as long as it's faster than 50 pulses per second to prevent flicker. In the circuit shown, it is strobing at 1 kHz because that was a convenient divider from which to draw the pulses U15.

Since any digit is on only one-tenth of the time, the peak current sent to each segment is higher than it would be for continuous operation, but the average current is actually less than it would be for continuous operation.

construction

Construction should present no problems. The PC board is shown in **fig. 4**. A top view is shown in **fig. 5**. Because of the number of lines on the circuit board, the use of a single-sided board requires several cross-over wires. The more ambitious might try a two-sided board. Layout is not critical. Bypass capacitors, 0.01 μF, are used at the V_{DD} pin of each IC where possible. These, together with the large power-supply filter capacitor, eliminate any oscillation problems. For those unable to make the board, the circuit can be hand wired.

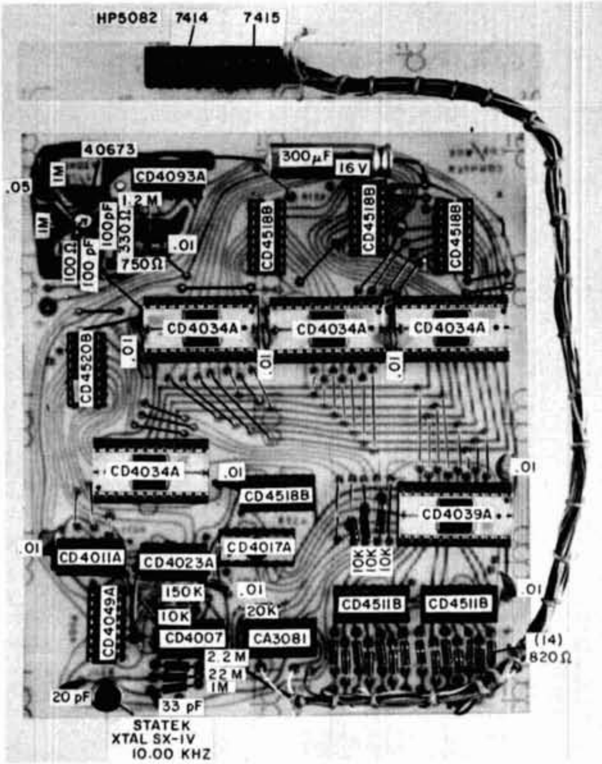

fig. 4. Top view of the layout of the portable counter.

There are absolutely no adjustments to be made for complete operation. Accuracy will depend entirely on the accuracy of the crystal clock. Use of a 0.01 percent accuracy crystal will give 0.01 percent accuracy $\pm$1 digit. The clock frequency may be trimmed slightly at C1 or C2 (**fig. 3**).

applications

The use of the counter is limitless. Complete portability with battery power allows its use in the home or field. It is excellent for setting teletype mark and space tones or fm repeater tones. Signal-generator frequencies as high as 4.5 MHz for TV alignment can be set more accurately. Another suggested use is musical instrument tuneup with a microphone pickup. The counter should be excellent for the piano or organ, especially electronic organs where direct pickup from the dividers is possible. With external circuits, it can be used in the car as the readout for a tachometer or speedometer. Surely you have already found a need for it.

acknowledgement

I would like to acknowledge the help received from RCA COS/MOS Applications Engineering and especially from Stanley Niemiec in choosing the ICs used in the circuit.

ham radio

interstage 50-ohm terminator for vhf converters

Many mixers and preamplifiers require a 50-ohm load — here's a circuit for providing a wideband resistive termination with minimum insertion loss

When cascading modules for receiving systems, it is often necessary to make sure that a particular stage is presented with a reasonably precise 50-ohm termination, over a relatively broad range of frequencies. One such requirement involves terminating a low-noise preamplifier which, although unconditionally stable at the operating frequency, is potentially unstable out-of-band. The highly reactive termination presented by a bandpass filter, operated off resonance, may cause the amplifier to oscillate at some undefined frequency, significantly degrading system noise figure and intermodulation performance. Another problem involves the image-frequency termination of double-balanced mixers. It has been shown that, to maximize a mixer's dynamic range, the i-f port must be properly matched – not only at the signal frequency, but also at any multiple-response frequencies appearing at the i-f.[1]

One method for obtaining a broadband interstage impedance match is based on the use of resistive attenuators between various stages.[2] Unfortunately, this approach introduces additional system losses which tend to degrade overall sensitivity. Another solution uses *interstage duplexers* which shunt the undesired frequency into a 50-ohm load.[3] This practice, however, is applicable only when the frequency of the undesired response is known and is well removed from the signal frequency. The circuit in **fig. 1** overcomes these shortcomings: It appears *virtually* lossless at the signal frequency and provides a wideband 50-ohm termination to any other frequency components which are present (limited only by the reactive nature of the load resistors at microwave frequencies). Additionally, this network provides the desired degree of *interstage selectivity*, as a function of the component values chosen.

The circuit of **fig. 1** is by no means original; it was brought to my attention by Gary Frey, W6KJD, who first encountered it in a commercial receiver design. Gary and I have both used the circuit extensively in vhf and uhf transmit and receive converters with considerable success.

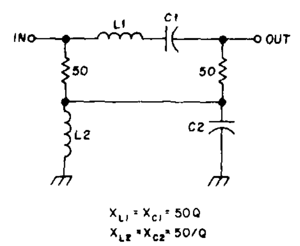

fig. 1. Vhf terminator which provides a wideband 50-ohm termination with minimum insertion loss. Component values are based on desired circuit Q, as discussed in the text. Equivalent circuits at resonance, and above and below resonance, are shown in fig. 2.

circuit operation

In the circuit of **fig. 1** capacitor C1 and inductor L1 form a series-resonant circuit at the operating frequency, while C2 and L2 are parallel resonant. At resonance the impedance of L1-C1 is at a minimum, the impedance of L2-C2 is maximum, and the signal path from input to output appears as a short circuit across the two 50-ohm

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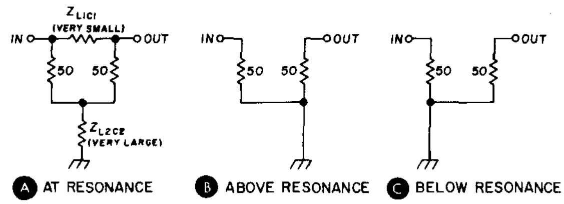


fig. 2. Equivalent circuit of the 50-ohm vhf terminator at resonance (A), above resonance (B), and below resonance (C).

resistors, as shown in **fig. 2A**. Thus the insertion loss of the network at resonance is minimal (due primarily to component losses in the resonant circuits).

At frequencies far above resonance, capacitors C1 and C2 appear as short circuits, and inductors L1 and L2 appear open. Thus the circuit is equivalent to that shown in **fig. 2B**, with input and output isolated from one another, and each port terminated in a 50-ohm load.

Well below the resonant frequency, both capacitors appear open, the two inductors may be thought of as short circuits, and the equivalent circuit of **fig. 2C** applies. Again, maximum isolation exists between the two ports, and each is terminated in 50 ohms.

A less clearly defined condition exists at frequencies slightly removed from resonance. Isolation is incomplete and the transfer coefficient is a function of circuit Q. Thus the selectivity characteristics of a single-pole band-pass filter are achieved. However, non-propagated signal components are not reflected, as would be the case with a simple resonant circuit. Rather, they are absorbed by the 50-ohm loads, giving the interstage network its wide-band terminating properties. Since reflected waves are not evident from either port, bilateral out-of-band isolation has been achieved.

determining circuit Q

Assuming minimum dissipative losses in the reactive components, circuit Q is primarily a function of the ratio of the reactances at resonance to the terminating impedance (50-ohms in this case). Selecting a desired circuit Q, component reactances at resonance are found from:

$$X_{L1} = X_{C1} = 50Q$$

$$X_{L2} = X_{C2} = 50/Q$$

Ideally, any desired circuit Q could be selected, and component values derived. Practical considerations, however, restrict practical values of Q to 10 or less. Higher Q is possible if passband insertion loss is not a significant consideration, but this usually requires that variable capacitors be used to set the network to resonance at the desired frequency. With lower values of Q, fixed components of standard values may be used with minimum circuit degradation.

The required Q is a function of the amount of out-of-band isolation which is desired, as well as the frequency separation between the signal and spurious components. It is useful to relate isolation requirements to ripple bandwidth, which is defined as center frequency divided by Q. As a rule of thumb, isolation is 10 dB for frequency components separated from resonance by ±3BW and 20 dB of isolation is achieved at the center frequency ±10BW.

In receiving converters, when terminating the i-f port of a balanced mixer, the rf feedthrough, LO feedthrough, and image frequency components may be separated from the i-f signal frequency by an order of magnitude or more. In such cases a Q of one may be entirely adequate to effectively isolate all spurious components. (Incidentally, a Q of unity is the only case for which C1 = C2 and L1 = L2).

Improperly terminated uhf preamplifiers, on the other hand, often tend to oscillate in the vhf spectrum (a common occurrence with Microcomm's RA-70, 432-MHz preamplifier, for example). Therefore, the terminator following a preamplifier should exhibit relatively high Q so it will provide adequate isolation at the frequency of potential instability, thus suppressing oscillation. An acceptable compromise seems to favor a Q of about 5. Insertion loss thus remains low (fractions of a dB), selectivity is moderate, and components have practical values and are non-critical.

Table 1 lists actual component values for terminators operating at various i-f and rf frequencies of interest to radio amateurs, assuming a circuit Q of 5. At the lower frequencies the circuits may be built successfully by using disc capacitors and either miniature molded rf chokes or hand-wound toroidal inductors. In the uhf region, the use of chip capacitors and microstripline inductors seems more appropriate. Of course, as frequency is increased, lead lengths must be kept to a minimum.

table 1. Interstage 50-ohm terminator component values (Q = 5) for various vhf and uhf amateur bands.

	frequency (MHz)						
	10.7	28	50	144	222	432	1296
L1 (nH)	3720	1420	796	276	179	92	30.7
C1 (pF)	59.5	22.7	12.7	4.4	2.9	1.5	0.5
L2 (nH)	149	56.8	31.8	11.1	7.2	3.7	1.2
C2 (pF)	1490	568	318	111	71.7	36.8	12.3

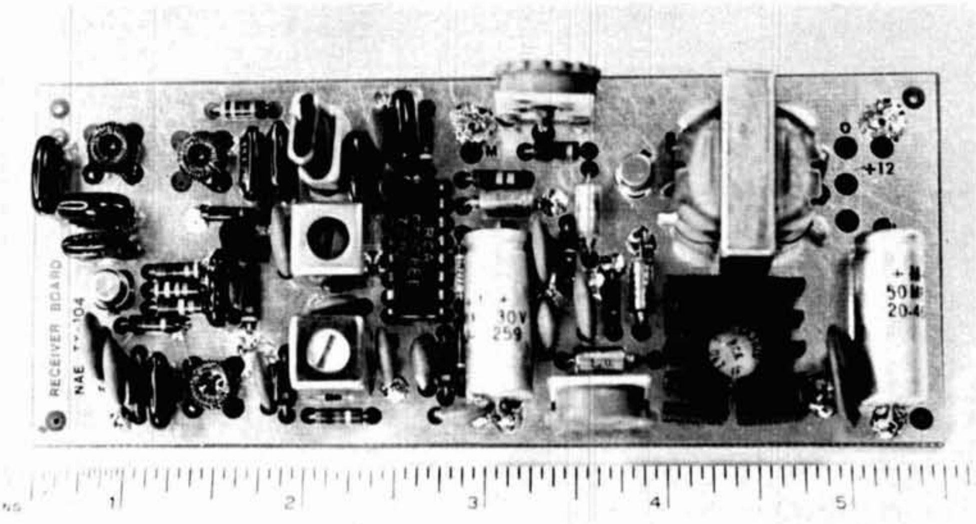
acknowledgements

I wish to thank Gary Frey, W6KJD, for bringing this terminator circuit to my attention, explaining its operation to me, and calculating the component values presented in **table 1**. And I owe a special thanks to Stan Savage, W6ABN; his frustration in fighting oscillations in not one, but two Microcomm preamplifiers, convinced me of the importance of providing an effective, broadband impedance match.

references

1. Peter Will, "Reactive Loads — The Big Mixer Menace," *Microwaves*, April, 1971, page 38.
2. Edward L. Meade, Jr., K1AGB, "Using the Double-Balanced Mixer in VHF Converters," *QST*, March, 1975, page 12.
3. Doug DeMaw, W1CER, "His Eminence — The Receiver," *QST*, June, 1976, page 27.

ham radio



the weekender

fixed-frequency receiver for WWV

Calibration standards are essential to ensure on-frequency operation when working with rf circuits. One source of such standards is the National Bureau of Standards station WWV. In addition to frequency calibration data, WWV provides propagation forecasts, geophysical alerts, and storm information. All this information is available to anyone with a receiver capable of receiving WWV signals.

Some work I was doing recently with crystal oscillators required a reference frequency that WWV could provide. I didn't have a receiver capable of tuning any of the NBS station frequencies, so I decided to design and build one. Requirements were that the receiver have high sensitivity, portability, low-power consumption, and low cost. This article provides design and construction information for a receiver that meets these requirements and which, with a little innovation, can be readily adapted for other uses in the hf spectrum.

By Andrew M. Hudor, Jr., Physics Department, University of Arizona, Tucson, Arizona 85721

The RCA CA3088 IC[1] was chosen as the basis for the receiver design. The converter, i-f, detector, audio preamplifier, agc, and a tuning meter output are all contained on this single chip! The block diagram of the CA3088 is shown in **fig. 1A**. Using this IC resulted in a saving of size, cost, and design time.

The CA3088 is not without its disadvantages, however. A good front end design is critical to receiver performance, since any signal lost there can't be recovered later, and any noise introduced at that point is amplified with the signal in the following circuits. A separate mixer and local oscillator provide superior performance to the simple converter circuit in the CA3088. Fortunately, the converter and i-f input on the IC are not committed to each other. **Fig. 1B** shows the internal schematic of the CA3088; it can be seen that the converter transistor has all of its terminals accessible. In fact, it has dc bias applied to its base, and only the ac paths are required to make it a crystal-controlled local oscillator.

Converter. A modified Pierce oscillator was designed, using the converter transistor of the CA3088. A mixer circuit was taken from reference 2. This circuit uses a junction fet, which gives more gain than a diode mixer and has less noise than a bipolar transistor. Fewer components were required to bias the junction fet, which was the main reason for selecting it over a mosfet.

Rf stage. A dual-gate-protected mosfet was used for the rf stage. This circuit was also taken from reference 2. The mosfet has excellent gain and low-noise performance, and the dual gates allow one gate to be used for the incoming signal, while agc can be applied to the other. The mosfet also has the advantage of not normally requiring neutralization when used in small-signal rf amplifiers. This greatly simplified alignment while eliminating a costly and space-consuming trimmer capacitor.

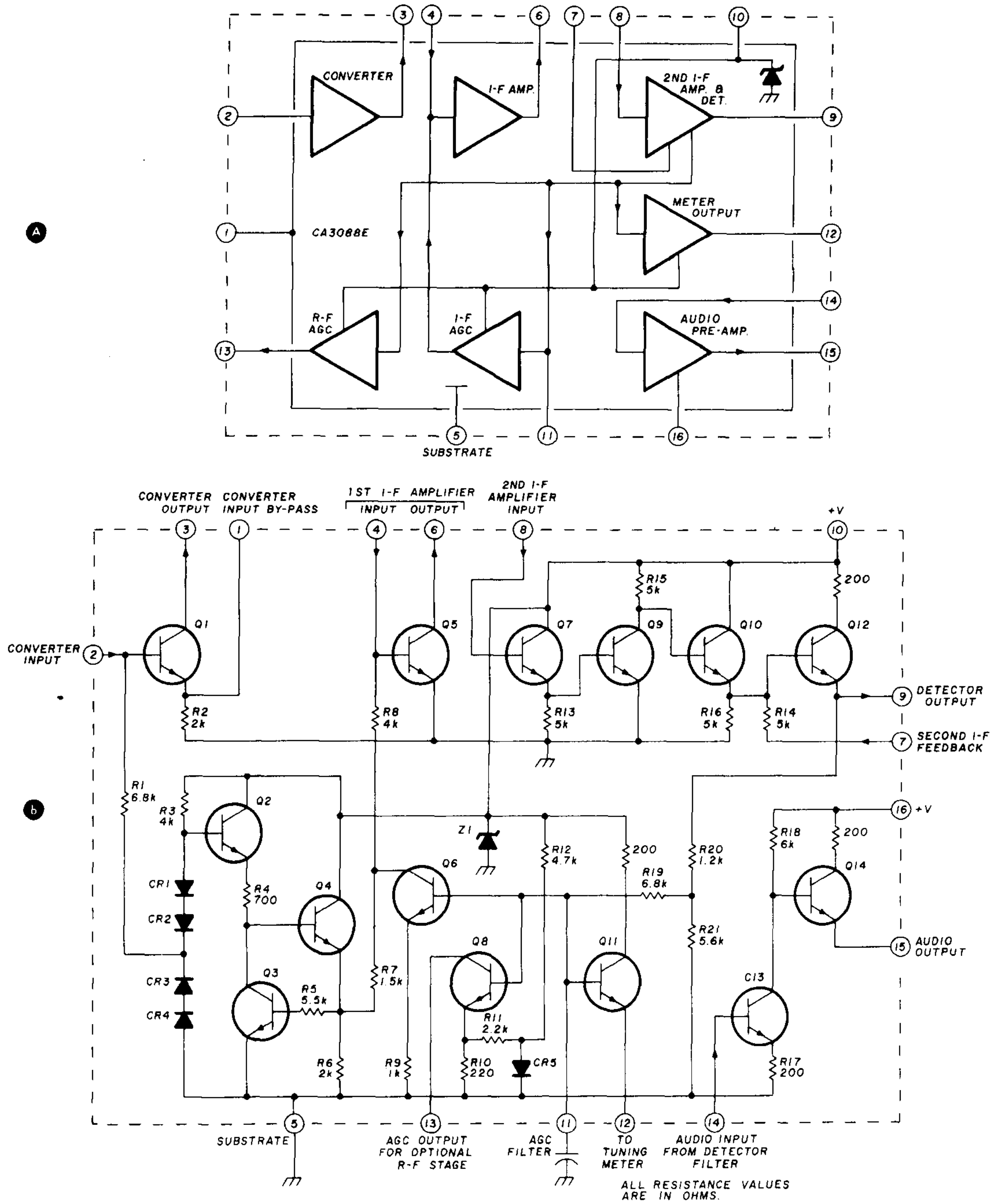


fig. 1. Block diagram of the RCA CA3088 receiver chip, A, and its internal schematic, B (from reference 1). In the WWV receiver design a separate local oscillator and mixer replace the converter circuit shown here.

Coils. The use of toroidal inductors also helped to reduce circuit complexity. The toroids have sufficient bandwidth so that adjustment is not necessary in the rf stage, mixer, or local oscillator. Although the very first version of the circuit used standard slug-tuned inductors, the toroids proved superior by making the circuit more stable. The area occupied by the inductor was reduced, adjustment was eliminated, and the toroids were actually lower in cost than the original coils.

I-f, detector, and audio. The i-f, detector, agc, and meter output were used as in reference 3. Transformers were used for the i-f stages instead of crystal filters since they were readily available and lower in cost.

The RCA CA3020 was selected for the audio-output stage, since I had a few of them in my parts stock. It turned out that using this IC yielded several advantages. The frequency response of the CA3020 can be shaped by selecting coupling and bypass capacitors. These components were selected to give an audio bandpass between 300 Hz and 3 kHz to reduce noise and increase signal intelligibility. The basic circuit for the audio output stage was taken from reference 4. The CA3020 had

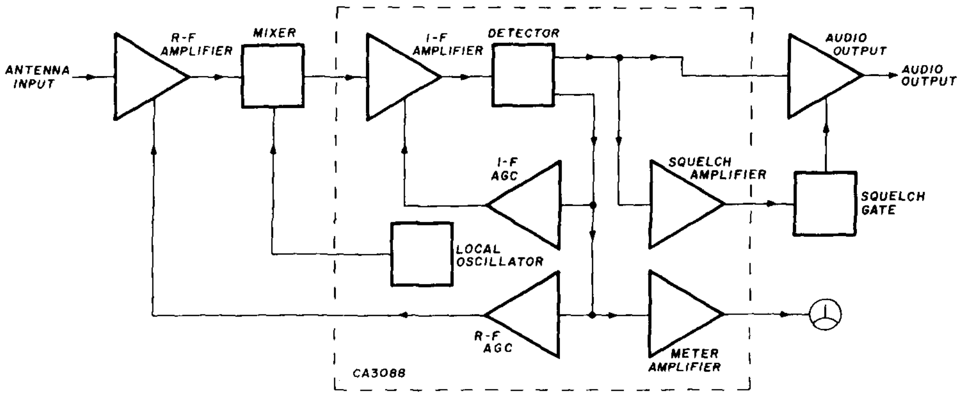


fig. 2. WWV receiver block diagram. An RCA CA3020 was added as an audio-output stage. The af circuit has a shaped frequency response, which reduces noise and increases intelligibility.

sufficient gain to be driven directly from the detector output of the CA3088. It also has squelch capability by application of a dc control signal to pin 11. The remaining audio preamplifier on the CA3088 was reconfigured, and with a few other components, a squelch circuit was added to the reciever.

The complete block diagram of the receiver is shown in **fig. 2**. The result of the design was a high-quality unit that has many other possibilities in addition to its orignial application as a fixed-frequency WWV receiver. Total parts cost was about $30.00.

construction

The 10-MHz WWV signal was chosen for the prototype design, since this frequency has the best daytime signal strength in my area. The circuit, **fig. 3**, can be used in any part of the hf spectrum with only minor component changes. **Table 1** gives component values for WWV, WWVH, and CHU frequencies. For local-oscillator frequencies below 20 MHz, a fundamental-cut crystal is used, and for frequencies above 20 MHz, an overtone crystal is used. When using the overtone crystal, C5 is replaced by a short and C6 is reduced to 10 pF. The load capacitance of the oscillator circuit is 32 pF and must be specified when ordering crystals.*

Ordinary inductors can be used for L1, L2 and L3, but I recommend toroids. Silver mica capacitors are used for C1-C6, as well as the 20 pF, 100 pF, and the 10 pF capacitors in the circuit. It's not advisable to replace these capacitors with ceramic types. The i-f transformers come as a set from Radio Shack (part number 273-1383). T1 has the gray core; T2 the white core. The other transformer and the oscillator coil are not used. If you substitute transformers, make certain they have the same pin connections if you use the printed circuit. T3, the output transformer, is a Radio Shack item, part number 273-1381. Almost any germanium diode can be used for D1 in place of the 1N277, and many silicon npn transistors can be used for Q3.

table 1. Receiver front-end component values for receiving WWV, WWVH, and CHU.

station	freq (MHz)	crystal freq (MHz)	C1 value (pF)	C2 value (pF)	C3,C4 values (pF)	C5 value (pF)	C6 value (pF)	turns	L1&L2 AWG	L1&L2 (mm)	L3 AWG	L3 (mm)	coil core†
WWV WWVH	2.50	2.955	300	820	220	30	150	66	32	(0.2)	32	(0.2)	T37-2
WWV WWVH	5.00	5.455	120	680	100	30	150	49	32	(0.2)	32	(0.2)	T37-2
WWV WWVH	10.00	10.455	56	330	47	30	150	40	32	(0.2)	32	(0.2)	T25-2
WWV WWVH	15.00	15.455	33	330	30	30	150	37	30	(0.25)	30	(0.25)	T25-6
WWV WWVH	20.00	20.455*	30	330	27	short	10	29	32	(0.2)	32	(0.2)	T25-6
WWV WWVH	25.00	25.455*	24	300	22	short	10	26	32	(0.2)	32	(0.2)	T25-6
CHU	3.33	3.785	300	820	220	30	150	50	30	(0.25)	30	(0.25)	T37-2
CHU	7.34	7.795	68	350	56	30	150	44	32	(0.2)	32	(0.2)	T37-2
CHU	14.67	15.125	33	330	30	30	150	36	32	(0.2)	32	(0.2)	T25-6

*Overtone crystal

†Available from Amidon Associates, 12033 Otsego St., North Hollywood, California 91607

Construction practices are not critical. Keep lead lengths short and use sufficient bypassing on the power buses. Oscillator tank coil L3 should be isolated from the rf tuned circuits to prevent desensitizing the rf amplifier. There are no special handling precautions for Q1, since it is a protected gate type.

A printed circuit layout is shown in **figs. 4** and **5**. This is a double-sided board, which uses one side as the

*Available from JAN Crystals, 2400 Crystal Drive, Fort Myers, Florida 33901.

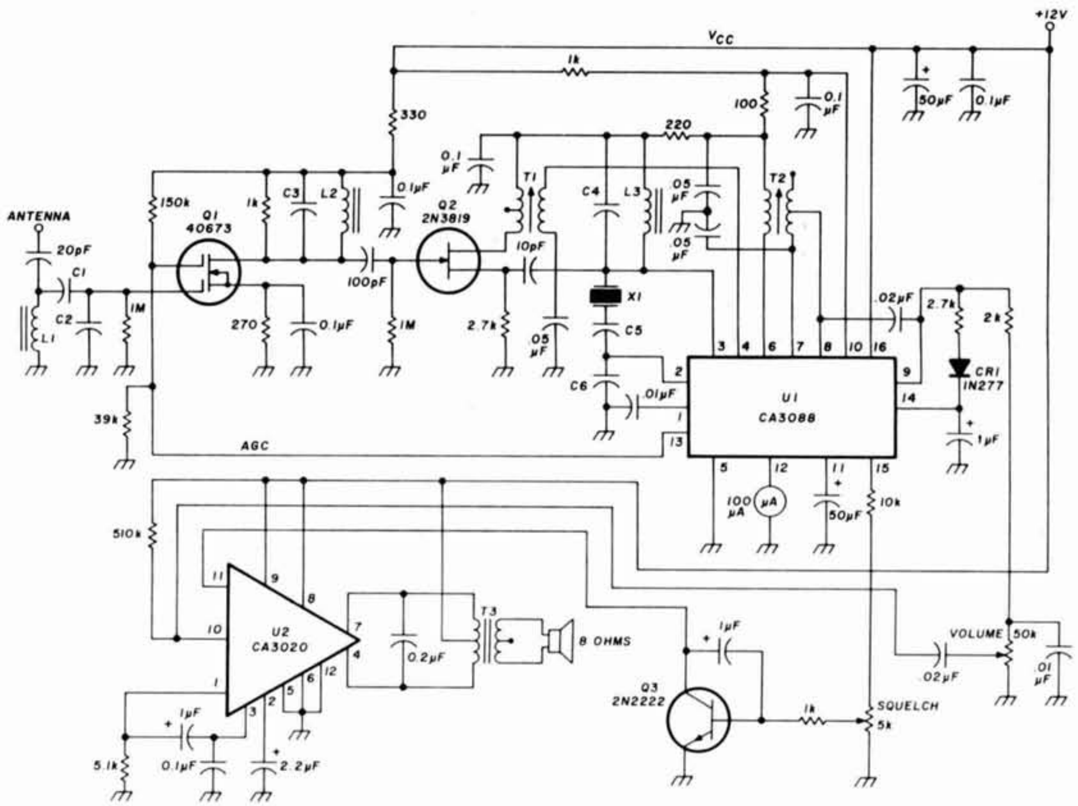
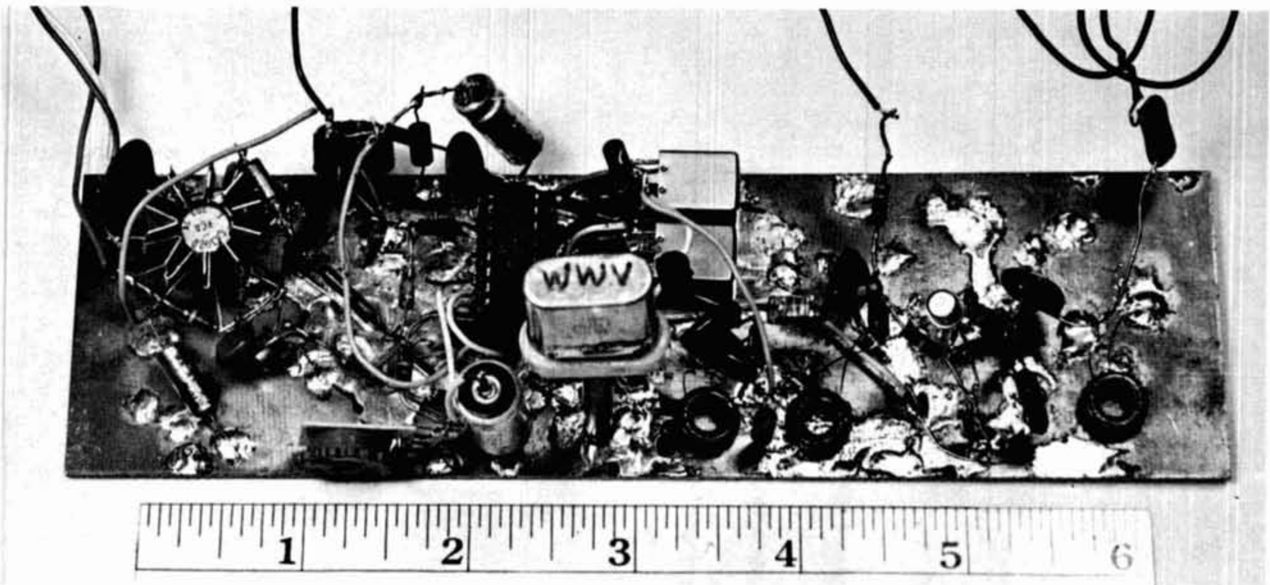


fig. 3. Receiver schematic. Broadband toroids are used instead of slug-tuned coils in the rf, mixer, and local-oscillator to reduce circuit complexity and increase stability.

ground plane. Some of the components are soldered to both sides of the board, so to avoid burned fingers and incinerated components, some planning is necessary before assembling the PC board. Solder the components that are connected to the ground plane first. Solder the shortest components first, then solder components in order of increasing height. This will prevent the difficulty of soldering a component to the ground plane that is surrounded by taller components already inserted.



Parts placement in the prototype version of the 10-MHz WWV receiver. Power requirements are 12 volts at 100 mA. For portable work, alkaline penlight cells will provide hours of service.

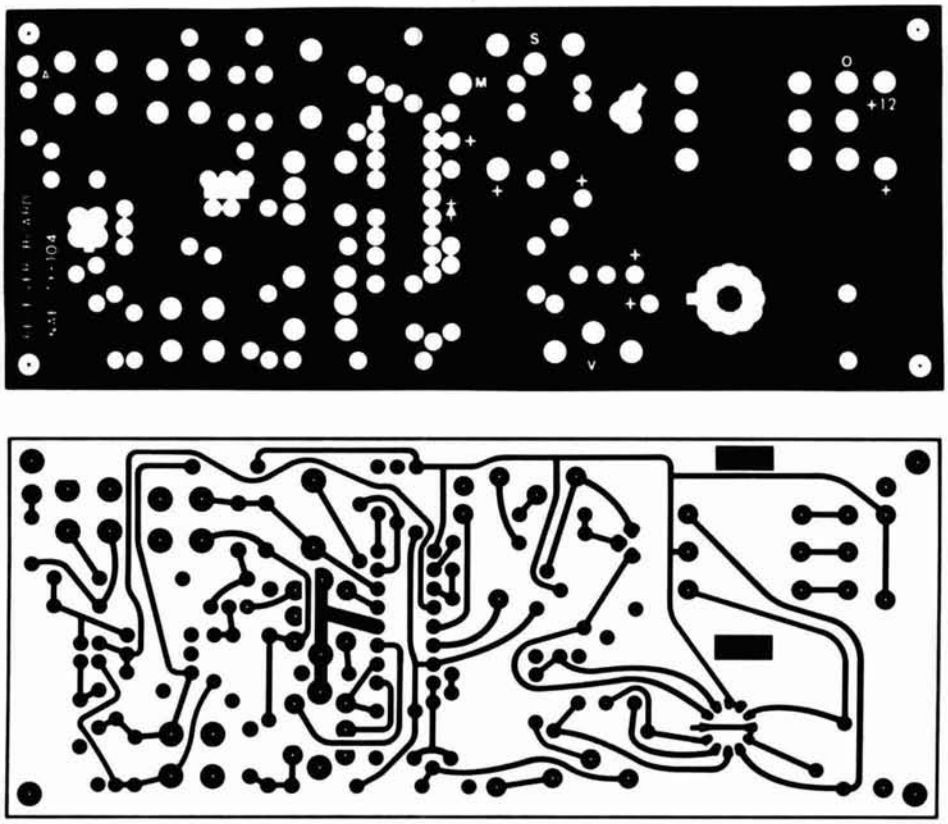


fig. 4 Top and bottom of the receiver PC board. A double-sided layout is used, with some of the components soldered to both sides of the board.

There is one jumper wire on the circuit board, which connects pins 5, 6, and 12 of the CA3020 to the ground plane. Solder a piece of bus wire through the hole from the ground plane to the pad underneath. Soldering the CA3020 into the board can be tricky. The pads are very small and overheating may cause them to lift. One method that works is to wrap a short piece of no. 18 (1mm) bus wire around the tip of the soldering iron and use this as a miniature tip to solder the IC. Plastic spacer pads should be used under Q1 and Q3 to prevent their cases from shorting to the ground plane. Finally, use a heat sink on the CA3020, since it dissipates enough power to get warm.

After assembly, a dc check of the circuit should be made. Apply 12 volts to the circuit and measure the current drawn. The current should be around 65 milliamperes. If it's much higher than this, remove power immediately and check the wiring.

alignment and operation

If the toroidal inductors are used, the receiver front end is adjustment-free and alignment is easy. Loosely

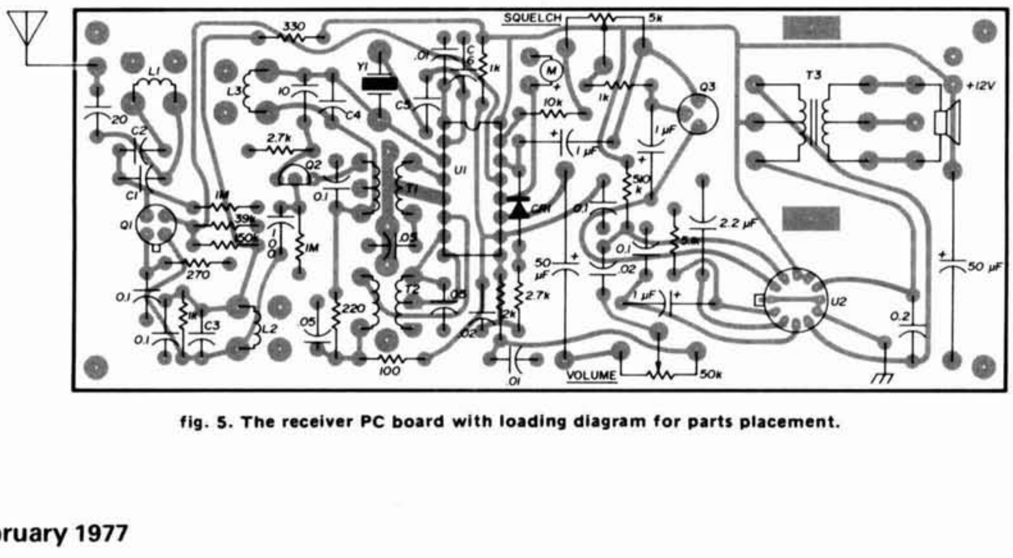


fig. 5. The receiver PC board with loading diagram for parts placement.

couple a generator to the antenna input and set it for the operating frequency. Adjust T2 for maximum output from the speaker or the tuning meter. Repeat for T1, and alignment is complete. In the case of the 10-MHz prototype, an antenna was connected to the reciever and the signal from WWV itself was used instead of a generator.

To align a receiver with slug-tuned coils, pull out the crystal and couple the generator into Q2 drain. Set the generator for 455 kHz, tune T2 for maximum, then tune T1 for maximum. Disconnect the generator and insert the crystal. Adjust L3 until an increase in background noise is heard in the speaker. Couple the generator into the antenna and set it for the operating frequency. Adjust L2 for maximum signal, then adjust L1 for maximum. Disconnect the generator and you are ready to go.

If stability problems develop with slug-tuned coils, it may be necessary to decrease the value of the 1k resistor across the rf stage output tank circuit. This lowers the tuned-circuit Q, so if instability remains, the only alternative may be to use the toroids.

A few feet of hookup wire is all that was needed for an antenna on the prototype. Receiver location, propagation conditions, and operating frequency will affect the amount of antenna required to get a good signal. Grounding also improves signal strength when the receiver is not used for portable work.

Any small, reasonably regulated power supply that can deliver 12 volts at 100 mA is suitable for powering the receiver. It's important that the voltage not exceed 12 volts, since the CA3020 rating will be exceeded. Batteries also work well, and some alkaline penlight cells will give hours of service.

performance

The prototype receiver has been very satisfactory in meeting all of the initial requirements. A receiver was also constructed for the 5-MHz WWV carrier and worked very well during late evening hours when the 10-MHz signal was weak. A bandswitching arrangement would be an excellent idea. The other frequencies have not been used on a prototype receiver, but performance should be equally good if the component values given in **table 1** are used.

Use of the ICs in the design reduced size and cost of the project tremendously. The CA3088 is very impressive in its performance, flexibility, and cost. It won't be surprising if other excellent designs result from its use.

references

1. *RCA Linear Integrated Circuits and MOS Devices Data Book*, RCA publication SSD-201B, 1974, page 446.

2. *Radio Amateur's Handbook*, ARRL, Newington, Connecticut, 51st Edition, 1974, page 246.

3. *RCA Linear Integrated Circuits and MOS Devices Data Book*, "Application Notes," RCA publication SSD-202B, 1974, page 318.

4. *RCA Linear Integrated Circuits Manual*, RCA publication IC-42, 1970, page 226.

ham radio

amateur television callsign generator

Callsign generator for amateur TV uses programmable memory to produce a professional-looking identification display without a camera

With the widespread availability of programmable ROMs (PROMs) it has become possible to build an ATV callsign generator with less effort than ever before. Such a generator allows you to identify your ATV station without the use of a camera. Carefully lettered signs that somehow don't look professional are a thing of the past at WB2CPA. My homemade RS-170 sync generator and vertical interval switcher has an *identify* switch that superimposes my call on the outgoing video.

The heart of my character generator is an ROM (Read Only Memory), and I used the readily available 32 x 8 PROM. The designation 32 x 8 means that the PROM has 8 outputs and 5 inputs ($32 = 2^5$). For each of the 32 possible states of the 5 inputs an 8-bit word will appear at the output. I used that fact to produce the TV image.

The first step in preparing your custom ROM is to make a *truth table* (**fig. 1**) representing your call. On a piece of graph paper mark 32 rows of 8 lines each. Now draw your call letters into these 256 boxes, striving for best appearance and fit.

Amateurs with two-by-three calls such as mine will find that only 7 of 8 lines can be filled to obtain well-proportioned letters. The graphic information (white spaces are logic 1 and dark spaces are logic 0) must now be placed into a ROM. There are several ways to do this. *Popular Electronics*[1] had plans for a programmer, and lists a vendor for the blank PROM.* Or you can have it done by any of several distributors who will program a memory to your truth table at reasonable cost.†

Five other ICs are needed to complete your callsign generator. The complete ROM must have all 32 locations addressed at least once per TV line and its 8 outputs sampled sequentially, advancing to the next after the end of each line on the screen (**fig. 2**).

*Signetics 8223, James Electronics, P.O. Box 822, Belmont, California 94002

†Solid State Systems, Box 617, Columbia, Missouri 65201.

By Jerry Pulice, WB2CPA, 143 Gibson Avenue, Staten Island, New York 10308

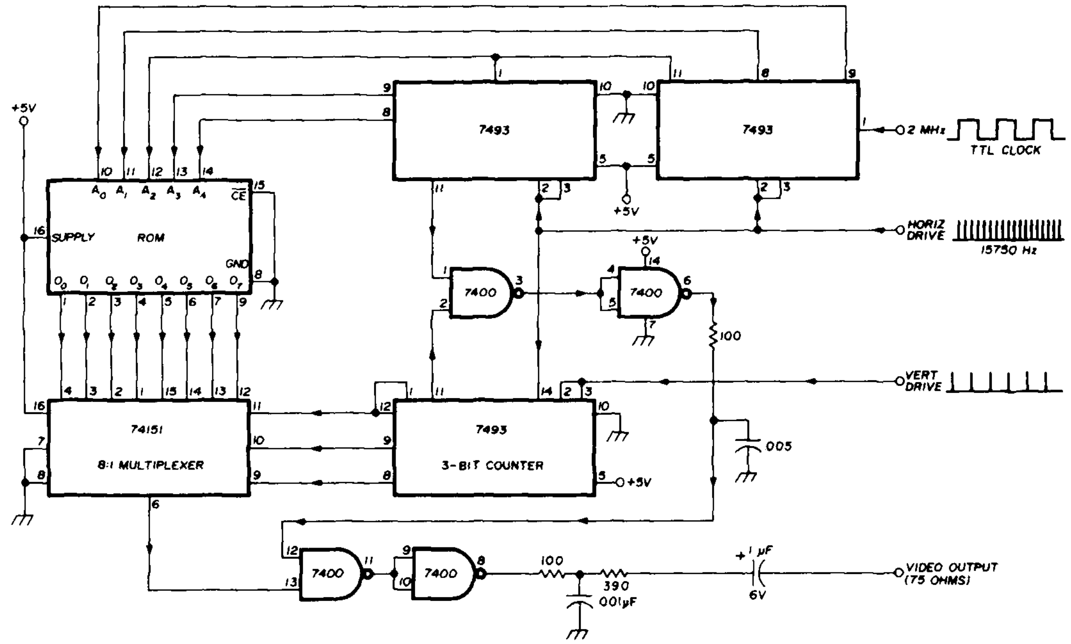


fig. 2. Logic diagram for the ATV callsign generator. Complete circuit operation is described in the text. The ROM pin connections shown here are valid for the AMI 27508/27509, 82523/82S123, MM5330/MM5331, HPROM 8256, or IM5600/5610.

I used a pair of 7493 binary counters to address the 32 words in the ROM. The rate that the 7493s are clocked affects the length of the characters on the screen. If you have 2- to 3-MHz TTL pulses somewhere in your sync generator (as I have) they can be used to clock the counter. If not, use the TTL oscillator shown in **fig. 3.**

The 74151 multiplexer must advance to the next ROM output once per scan line. Its 3-bit counter is clocked by horizontal drive pulses from the sync generator. The characters on the screen should appear in the same position on each field in order to remain stationary. Therefore, reset pulses are applied to the counters. Positive-going horizontal drive pulses reset the 5-bit word counters and positive-going vertical drive pulses reset the 3-bit line counters. For the display to be stable, these pulses must come from the same sync generator.

Video output of either polarity can then be taken

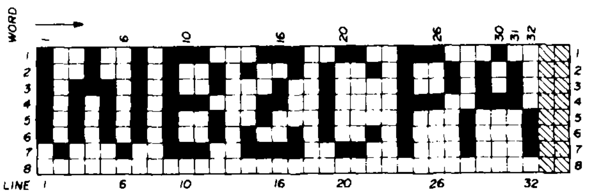


fig. 1. Truth table for the ATV callsign generator showing graphic layout of WB2CPA's callsign. Available space can be layed out for any two-by-three amateur callsign, or for shorter calls.

from the 74151 multiplexer. Extra bits from the word and line counters are used to gate the video *on* only 50 percent of the time. This puts a border around the letters to increase clarity.

To add the video to an existing 75-ohm source, merely connect the vertical and horizontal drive from the source and couple it in parallel with the TTL output through the RC network shown in **fig. 2.**

It is illegal to add the suffix "TV" to an amateur station callsign, so I added a touch to my generator that uses the fact that my PROMs have tri-state outputs. I have two ROMs in parallel and alternate between them by using their chip-enable inputs. In this way the image *alternates* between WB2CPA and TV. This impresses the heck out of visitors to the shack!

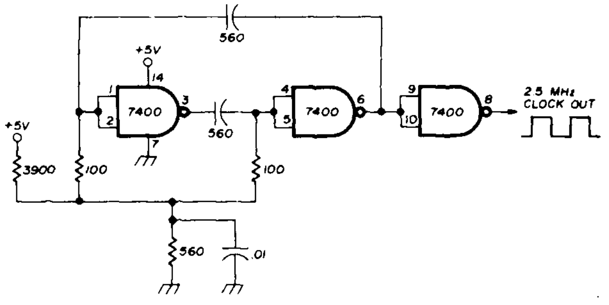


fig. 3. Suggested TTL oscillator circuit for use with the ATV callsign generator.

reference

1. Robert D. Pascoe, "How to Program Read-Only Memories," *Popular Electronics*, July, 1975, page 27.

ham radio

how to make custom capacitors for your homebrew projects

Construction details for making your own low-inductance capacitors from PC-board stock

Recently the need for some low-value, low-inductance capacitors led me on a merry chase through local radio parts outlets. The capacitors I needed were either not in stock or too expensive. I'm used to building almost everything I need, as are most vhf men, but in this case it took a bit more thought.

After several dismal attempts at making capacitors with casting resin, thin brass sheet, paper, and glue, the light suddenly snapped on – printed-circuit board! PC boards are available in a variety of thicknesses and dielectric material at reasonable prices. I chose the epoxy paper type (double-side board) and estimated the dielectric constant at 3.3. Material thickness was 0.0625 inch (1.59mm).

computations

After cutting several pieces of PC-board material with a nibbling tool, I computed the capacitance values (approximately, but I was surprisingly close!) and verified them on a "Mickey Miker." I attribute any small errors to lack of knowledge of the exact dielectric constant of the PC-board material. The dimensions and

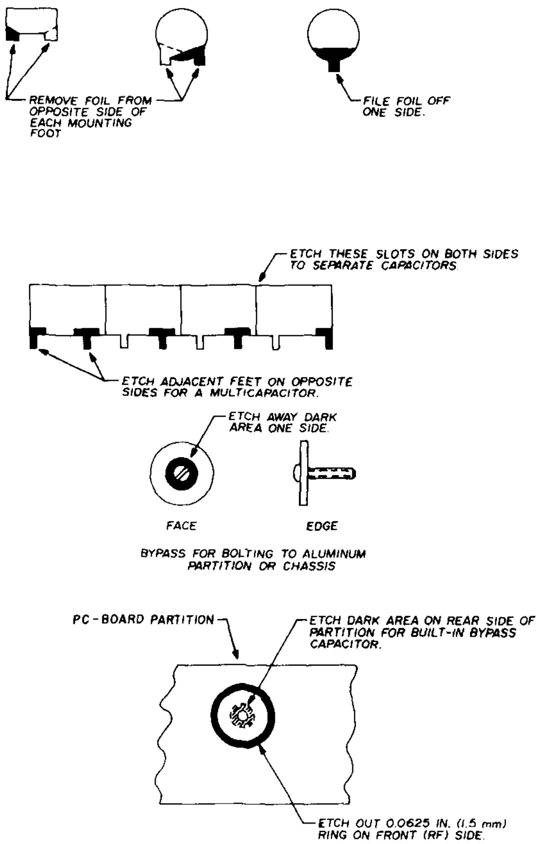


fig. 1. Construction details for making your custom capacitors from PC-board material. All have low inductance and are suitable for use with printed circuits. Table 2 gives capacitance values for various diameters, using double-sided epoxy paper type PC-board material 0.0625 in. (1.59mm) thick.

By Martin Beck, WBØESV, 1637 Hood, Wichita, Kansas 67203

table 1. Matrix showing capacitance values for square or rectangular shapes. Accuracies are sufficient for experimental amateur work.

dimension A, in. (mm)	dimension B, in. (mm) 0.25(6.5)	0.5(12.5)	0.75(19)	1.0(25.5)	1.25(31.8)	1.5(38)	1.75(44.5)	2.0(51)
	capacitance, pF							
0.25(6.5)	0.7	1.5	2	3	4	4.5	5	6
0.5(12.5)	1.5	3	4.5	6	7	9	10	12
0.75(19)	2	4.5	7	9	11	13	15	18
1.0(25.5)	3	6	9	12	15	18	21	24
1.25(31.8)	4	7	11	15	18	22	26	30
1.5(38)	4.5	9	13	18	22	27	31	35
1.75(44.5)	5	10	15	21	26	31	36	41
2.0(51)	6	12	18	24	30	35	41	47

values in the tables are sufficient for amateur purposes anyway, since our work is mostly cut and try. The equation used for computing capacitance is:

$$C = 0.224 \frac{KA}{d(n-1)} \qquad (1)$$

where

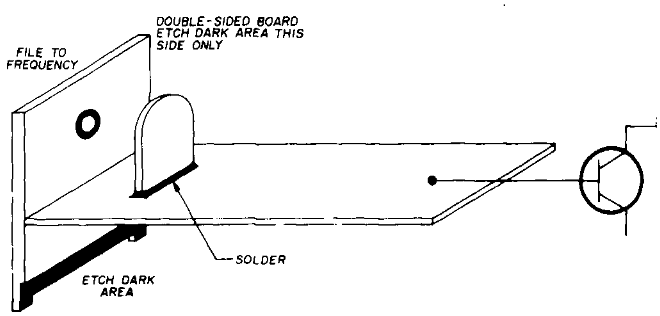
C = capacitance (pF)
K = dielectric constant
A = area of one plate (square inches)
d = spacing of plates (PC-board thickness, inches)
n = number of plates

For using metric equivalents **eq. 1** becomes:

$$C = 0.00882 \frac{KA}{d(n-1)} \qquad (2)$$

where

A = area of one plate (mm^2)
d = spacing of plates (PC-board thickness, mm)



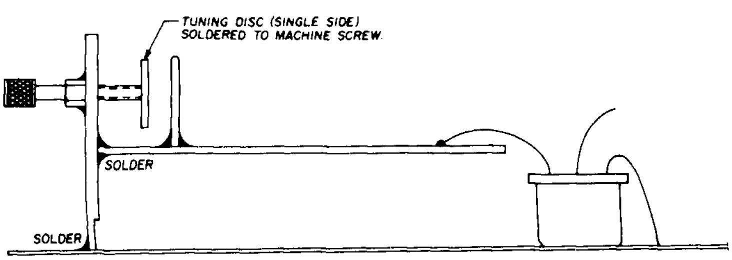


fig. 2. A capacitor and stripline inductor combination for microwave applications.

Examples

Using $d = 0.0625$ inch, $A = 2$ inch^2 and $K = 3.3$:

$$C = 0.224 \frac{3.3 \times 2.0}{0.0625 \times 1} = 23.65\ pF$$

Using $d = 1.59$ mm, $A = 1290$ mm^2 and $K = 3.3$:

$$C = 0.00882 \frac{3.3 \times 1290}{1.59 \times 1} = 23.61\ pF$$

The small difference in the two examples is due to roundoff errors in making the metric conversion. **Table 1** is a matrix allowing you to choose capacitance values for various plate dimensions, using square or rectangular shapes, and **table 2** is a handy reference for round capacitors.

table 2. Capacitance values for round capacitors made as shown in fig. 1.

dimension D, in.	(mm)	capacitance, pF
0.25	(6.5)	0.58
0.3125	(8.0)	0.98
0.375	(9.5)	1.30
0.4375	(11.0)	1.77
0.5	(12.5)	2.32
0.5625	(14.5)	2.93
0.625	(16.0)	3.62
0.6875	(17.5)	4.38
0.75	(19.0)	5.22
0.8125	(20.5)	6.09
0.875	(22.0)	7.11
0.9375	(24.0)	8.15
1.0	(25.5)	9.28

construction

The capacitors in **fig. 1** have very low inductance and are suitable for mounting on printed circuits. An interesting point is that to achieve the perfect value for your needs you can sand or file an edge a bit at a time, slowly reducing the capacitance. **Fig. 2** shows how to make a PC-board capacitor and stripline inductor combination for microwave circuits. No doubt with a little thought many other capacitor applications will come to mind.

ham radio

thoughts to consider about the

New Drake TR-4Cw

Of the many questions and comments we receive, we feel the following are very significant. Please spend a moment, and consider these points with us:

The TR-4Cw still uses tubes.

True. While using a combination of transistors and tubes, the TR-4 system makes greater use of tubes. Tubes are easy to change, and with the use of a spares kit, they can be readily replaced from the jungles of the Amazon to the arctic tundra—anytime, anyplace.

Also, the TR-4 system uses a *triple* tube power amplifier. It runs more power *output* than most transceivers run *input.* Serious DX-ers and contesters know the value of power when the going gets rough in heavy QRM. The system is also ideal to drive the various grounded grid linears that require higher drive levels.

The TR-4 system has been around a long time— what does it offer me today?

True again. The system has been around, and improved, over a 13 year period. It is one of the most "bug-free" systems we know.

Interestingly, the TR-4Cw offers some features still not found on most "new" rigs today. For example, frequency tuning in the TR-4 system is accomplished by the use of a precision permeability tuned oscillator (PTO). This makes use of a slug traveling through a coil instead of the older variable capacitor technique. The PTO gives us extra good frequency stability and dial linearity. Speaking of something old, the variable capacitor technique dates back over 50 years!

The cw filter in the TR-4Cw can be independently switched from the front panel. You're not "locked" in to the cw filter when in cw mode as in most transceivers. Many operators prefer to tune randomly with the wider filter. You can do it with the TR-4Cw.

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More Details? CHECK–OFF Page 118

isolating parallel currents in rf amplifiers

Construction techniques improving amplifiers stability using toroid cores and ferrite beads

Problems with radio-frequency amplifiers first occurred when I decided to build them on a metal chassis, which was then put inside a metal box. I also used large areas of the chassis as part of the conductors for the input and output tuned circuits. This construction technique resulted in a very low impedance path for the conduction of parallel currents that find their way into the amplifier from the antenna. How I solved instability problems in an rf amplifier resulting from these parallel currents is the subject of this article.

parallel currents

Out-of-band signals propagating down the antenna transmission line as parallel currents are not rejected by the amplifier tuned circuits. These currents pass straight on to the mixer either directly or by being induced into amplifier tuned circuits by way of the chassis. A typical path taken by the parallel currents in the input section of an rf amplifier is shown in **fig. 1**. These currents mix with strong in-band signals causing intermodulation products that produce distortion.[1]

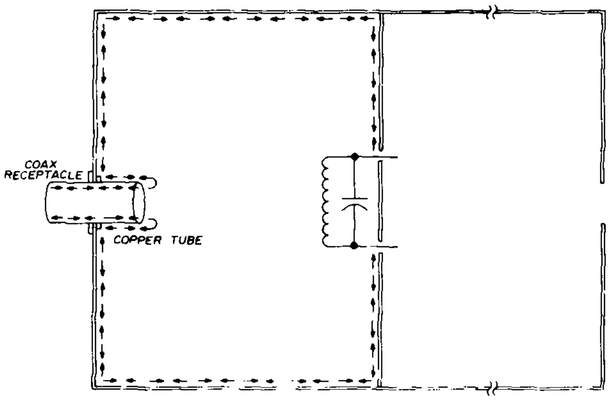

fig. 1. Path of parallel currents in the input section of an rf amplifier. The currents are induced in the antenna, travel down the braid of the transmission-line coax cable, and find their way into the amplifier to cause IMD and feedback problems.

Fig. 2 shows how parallel currents are set up on the *antenna and coax feed system*. The currents are apparently at a much higher level than is generally realized,

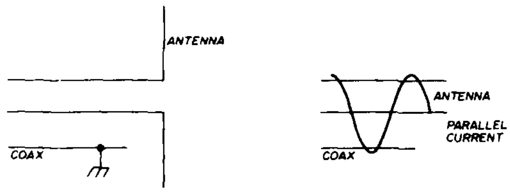

fig. 2. How parallel currents are set up on the antenna and feed line. The antenna does not balance out these currents. They are in phase on the antenna element.

especially when the antenna is mounted on a large metal object such as a ship, or when mounted on a building containing extensive metal conduits and electrical wiring. The parallel currents travel along these conducting devices then are induced into the outer side of the coax cable, travel up it to the antenna and then down both inner conductor and inside of the coax braid. The antenna does not balance out these currents; they *are in phase* on both sides of the antenna element. Such currents also cause increased levels of internal feedback in an rf amplifier, which make it difficult to obtain good neutralizing adjustments.

isolation method

The schematic of **fig. 3** shows methods I used to solve the problems caused by parallel currents. Input and output link coils and lengths of copper tubing on the *coax connectors* separate true antenna currents from parallel currents. A high impedance to the parallel currents is provided by the toroid cores placed over the copper tubing on input and output connectors, so the

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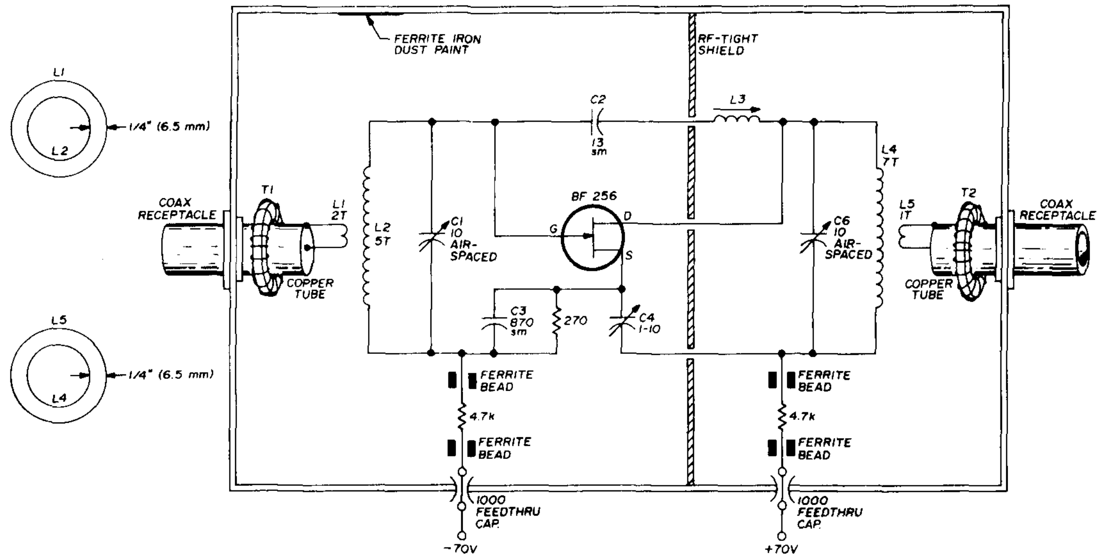

fig. 3. Rf amplifier with improved isolation of parallel currents between input and output. Sketches at top are end views showing how input and output links are coupled to the amplifier-tuned circuits. The T-68-10 toroid holes were enlarged slightly to slip over the copper tubing soldered to the coax receptacles.

currents can't reach the following stage. Ferrite beads on the wiring carrying input voltage to the amplifier provide further isolation. An rf-tight shield placed across the center of the box isolates input and output circuits. Finally, a coat of ferrite-dust paint was applied to the inside of the box.

The amplifier shown in **fig. 3** has been fully tested on the air. The only thing that doesn't appear to improve matters is the ferrite dust painted on the inside of the box. The toroids improved amplifier stability and neutralizing adjustments.

reference

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ham radio

loops and reflectors

ZL1BN's article on corner-fed loop antennas for low and medium frequency use inspired some thoughts of improving my own forty-meter performance, especially for long-haul and DX work.* I immediately built a loop for forty meters and suspended it from a thirty-foot mast attached to the center support of my neighbor's back yard chain link fence. This happened to be a fortuitous choice for a couple of reasons, since my neighbor — W2OSY — and I have been hamming together for a number of years, and his fence has been used on a shared basis for many antenna projects. The second reason is a bit more technical, because the fence turned out to be an excellent linear reflector element for the loop.

In order that the horizontal element of the triangle be raised sufficiently above ground to prevent decapitating my son when he mowed the lawn, I had to slant the antenna by pulling the bottom portion horizontally away from the fence. This was done with light nylon line attached to each lower corner, and resulted in the bottom element of the loop being about ten feet off the ground. It turned out that the median distance from the loop center to the top of the fence was about 0.15 wavelength on forty; not bad for a reflector. I fed the antenna with RG58 coaxial cable at the corner closest to the shack, and tuned my transmitter to check on the swr. Surprise! The swr was below 2:1 over the entire CW portion of the band. On-the-air checks showed that my signals were excellent into eastern Europe and the Mediterranean, as well as into western Africa. Results in the other direction (to the west) showed a very pronounced front-to-back ratio, with only very high-angle, close-in signals being received. No West Coast U.S. signals were heard during many hours of late evening operation, contrary to my usual experience.

I'm sure that a triangular tuned reflector added to the loop would show even better performance; but as it is, this antenna into Europe out-performs any forty meter antenna I've ever used, so I want to say thanks to Barry Kirkwood, ZL1BN, for a most timely and satisfactory aid to my DX efforts. The corner-fed system in particular makes me and my transmitter very happy, because I don't need a tuner anymore. Now, before snow flies, I'm planning a delta loop for 75 and 80 meters at my new QTH. Sure wish I had that fence in my back yard here, too!

Jim Gray, W2EUQ

*April, 1976, *ham radio*

silver plating made easy

Silver plating is neither difficult nor expensive — this article shows you how

The controversy as to the merit of silver plating has existed for many years and from time to time is still debated on the ham bands. The experts are nearly unanimous in recommending silver plating, particularly on vhf and microwave conducting surfaces.

Aside from the improvement in electrical performance that is generally claimed, there is, in my opinion, a more important reason for silver plating – preservation. It would be interesting to wind a pair of two-meter coils from bare copper wire, silver plate one, and leave the other unplated. A comparison of their performance should show little or no noticeable difference. However, repeat the experiment two years, or even six months, later and the results may be entirely different. The silver-plated coil would very likely show superior performance, and it would look better.

materials

Brass and copper are ideal raw materials frequently used for homebrew projects. Both are easy to work and they lend themselves to silver plating. Thin sheet stock and various sizes of tubing can be purchased in many hobby shops. Scrap brass can often be purchased in a wide variety of sizes from junk shops, and at reasonable prices. Flashing copper may be available from a local roofing contractor or hardware store. It is also possible to purchase brass or copper from steel supply houses, but the cost is higher and there are other constraints, such as minimum order quantities which are in excess of the average amateur's use.

Table 1. Relative resistivities of various metals used in amateur projects.

Silver	0.94
Copper	1.00
Aluminum	1.60
Zinc	3.40
Brass	3.70-4.90
Nickel	5.10
Tin	6.70
Lead	12.80

silver plating

Aside from the silver plating controversy, there are theoretical considerations which show that circuit losses increase with frequency. One way to reduce losses is to use silver plating. Because of a phenomenon called skin-effect,[1] rf current tends to concentrate near the surface of a conductor. This is caused by the way the magnetic field, produced by the current flowing in the wire, is distributed in and about the conductor.[2] The inductance of the wire is greater at its center, thus providing an easier path for the current near the outside surface.

Skin depth is defined as that distance below the surface of the conductor where the current density has dropped to about 37 per cent of the density at the surface.[3] For example, a straight round wire at 144 MHz has a skin depth of approximately 0.216 mils (0.0055mm). As the frequency increases, the skin depth decreases according to the following relationship:

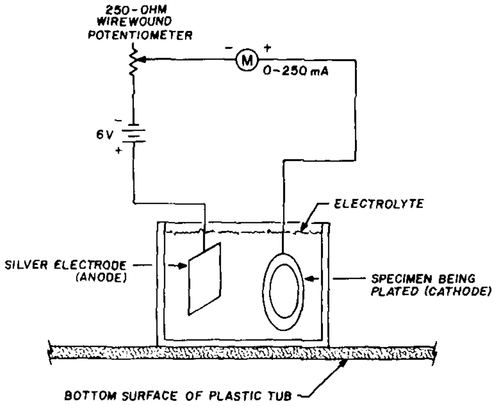

fig. 1. Hookup for silver plating. Recipe for the silver-plating solution (electrolyte) is given in table 2.

$$d = 2.59 \sqrt{\frac{1}{f}} \text{ mils}$$

where f is in MHz. At 220 MHz, skin depth is about 0.175 mils (0.0044mm). At 432 MHz, it is only about 0.125 mils (0.0032mm).

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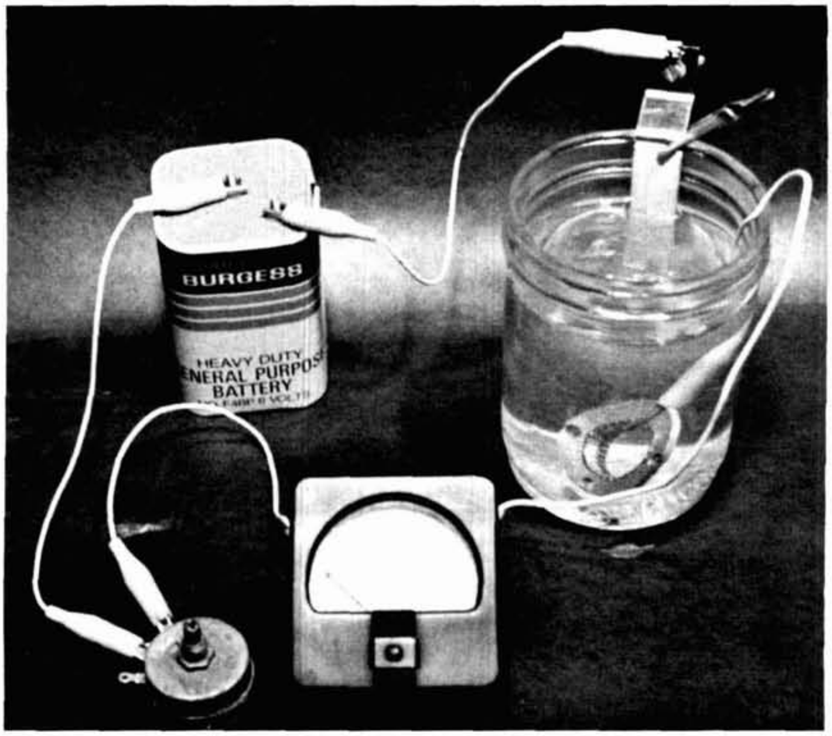

Table 1 lists the relative resistivities of various metals likely to be used for amateur construction projects.[4] While clean copper is only slightly more resistive than silver, the difference becomes greater as the copper oxidizes. Note that there is an obvious need to silver plate brass.

The types and quantities of chemicals needed to mix a gallon of silver-plating solution are given in **table 2**. The chemicals should be poured slowly while stirring into a wide-mouth jar containing about two-thirds of a gallon (2.5 liters) of distilled water. Add the chemicals in the order shown in the table. Mixing should be done out-of-doors where there is adequate ventilation since a small amount of cyanide gas will be given off in the mixing process. *Caution: Cyanide gas is poisonous — avoid contact of the solution with open sores and avoid prolonged breathing of the vapors.*

After the plating solution has been prepared, it should be stored in a one-gallon (4 liter) jug with a narrow neck and a screw cap. Pour the plating solution into the gallon jug with the aid of a small aluminum funnel. Add distilled water to bring the volume up to a full gallon (3.8 liters). Be sure to store the solution out of reach of children.

current density

The current density recommended by experienced platers is between 5 and 15 amperes per square foot (5 to 16 mA per square cm) of plating surface. On this basis, a piece of 0.032-inch (0.8mm) thick brass plate, one inch (25mm) square requires a plating current of between 35 and 105 milliamperes, if the edges are neglected. The thickness of the deposited silver depends on the amount of current and the plating time. Experience has shown that for hobby uses, as a general rule, it is seldom necessary to exceed a few hundred milliamperes of current for more than a half hour.

plating thickness

The electrochemical equivalent for silver is 4.0255 grams per ampere-hour.[5] This means one gram will be plated in one hour at a current of 248 milliamperes. A one-ounce spoon of electrolytic silver weighs approximately 28 grams. Since its specific gravity is 10.5, its volume is 28/10.5 or 2.7 cc. When plating for a half hour at 100 milliamperes, 0.201 grams is deposited, which is equivalent to 0.019 cc (0.201/10.5 = 0.019). The silver spoon will be completely used up after 140 such plating sessions.

The thickness of silver deposited on a thin, one-inch-square (6.4 square cm) plate in a half hour at 100 milliamperes is calculated as follows:

$$t = \frac{0.061V}{A}$$

where: t = thickness (mils)
V = volume deposited (cc)
A = surface area (square inches)

$$t = \frac{0.061 \cdot 0.019}{2 \cdot 1^2} = 0.580 \ mil$$

The figure 2 appears in the denominator because the 1-inch square plate has two sides. This is a reasonable thickness for hobby work, and it exceeds the skin depth at frequencies above 100 MHz. At lower frequencies, the silver serves more as a protective layer than a low-loss plating.

The chemical plating process[6] involves an electrolyte ionized by the applied voltage. Negative ions drift from the cathode to the silver anode. The silver breaks up into positive ions which go into solution. The free electrons travel over the external circuit to the cathode to combine with silver ions coming out of solution, thus forming metallic silver. The silver anode is gradually dissolved and conveyed to the cathode. The amount and composition of the electrolytic does not change in this process. Except for a very gradual contamination from other causes, the electrolyte has indefinite life.

Table 2. Silver-plating solution recipe.

Silver cyanide	4.8 oz (136 grams)
Potassium cyanide	8.0 oz (226 grams)
Potassium carbonate	2.0 oz (57 grams)
Distilled water	1.0 gal (3.8 liters)

preparation for plating

The most important word of advice for the would-be plater is cleanliness. Not only must the specimen to be plated be spotlessly clean, care should be taken to avoid contaminating the electrolyte with cleaning agents. Two plastic pails should be used for cleaning purposes. Both should be located in one compartment of a double sanitary tub. The plating solution should be located in the other compartment. One pail should be filled with cold tap water to which is added a quarter-cup (2 ounces or 59cc) of liquid *All* detergent, or equivalent. This pail will serve for cleaning the specimen to be plated. The other pail should be located under the cold-water tap, with the water running, and used for rinsing purposes. This will help to avoid contaminating the electrolyte.

Very fine steel wool such as 000 grade, saturated in detergent, makes an excellent scrubber, especially for brass which is more difficult to clean than copper. After scrubbing, rinse the specimen and submerge it in the electrolyte, but out of contact with the silver anode. Adjust the current to 30 milliamperes and remove the specimen after one or two minutes of plating.

Rinse and examine the specimen for chalky regions which identify areas not initially clean. Repeat the scrubbing process, wash, and return the specimen to the electrolyte. After another few minutes, repeat the inspection process. Seldom will the cleaning process have to be repeated more than twice. A final wash and continued plating for 15 to 30 minutes at a current of 100 milliamperes will complete the job. While larger specimens require longer plating times, the process can be speeded up if the current is increased. However, if the plating is done too rapidly, a chalky finish may appear which rubs off when scrubbed with steel wool and detergent. It is prefereable to plate at a slow rate. It is a good idea to remove the specimen after ten or fifteen minutes to assure that the plating speed is not too fast. Also, while the specimen is in the final plating process, change its position from time to time relative to the anode to assure a more uniform plating.

The last step is to wash and soak the piece in the detergent pail for ten minutes or more. Run tap water into the pail until the water is clear. This washes away traces of electrolyte which might otherwise leave spots. A final word of advice: Be sure your hands are clean when handling the freshly plated specimen; skin oils leave finger prints. Dry the plated specimen as completely as possible with a soft cloth to avoid water marks.

preserving the shine

While your hands are still clean, use masking tape to cover those areas of the specimen which will be used for electrical contact with other parts. Then spray the specimen on both sides with a thin coating of clear enamel. An inexpensive, non-toxic clear enamel called *One Coat*, is distributed by Korvettes, and does a fine job of protecting the silver surface from discoloration due to oxidation. If the instructions given here are carefully followed, the silver-plated specimen will be a thing of beauty, with a bright silver coat.

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bandspreading techniques

for resonant circuits

How to calculate capacitance values for tuning the desired bandwidth in variable-frequency oscillators, bandpass filters, and other tuned circuits

Adding series and parallel capacitors to a variable tuning capacitor are common techniques in bandspreading a vfo or other tuned circuit. However, very little information has been published on finding the correct values of the added capacitance. The calculations given here are relatively simple and assure the designer of quickly finding the correct values.

An inexpensive pocket calculator with a square-root function will improve accuracy and help keep track of the decimal point. Test equipment is needed only if capacitance values are unknown, and a grid dipper with a few standard, known-value capacitors will do the job nicely.

All calculations are simple algebra, so don't be worried about the technique. All you have to do is keep the decimal points in their proper places and plug in the correct values where they're called for.

basis for the technique

The key to this technique is based on the ratio of maximum to minimum capacitance and frequency. The basic resonance formula,

$$f^2 = \frac{25330.3}{LC} \qquad (1)$$

where f is in megahertz, L in microhenries, and C in picofarads, shows that capacitance is the inverse *square* of frequency. If you only think in terms of band limits, then the capacitance *ratio* is equal to the *square* of the frequency *ratio*.

Although the actual value of the L and C components is important in determining the impedance of the circuit, only the ratio of the variable capacitor will determine the ratio of the frequency range. Since it is usual practice to use variable capacitors in vfo design (as opposed to variable inductors), you can assume that inductance is only fixed or trimmable. The calculations will also give total circuit capacitance for determining circuit inductance and impedance. Following are several of the constants which are used in the bandspreading calculations:

$$D = \textit{Desired capacitance ratio}$$
$$= (f_{max}/f_{min})^2$$

where f_{max} and f_{min} are the band limits desired

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V = Variable capacitor's capacitance ratio, maximum to minimum
C_v = Variable capacitor, maximum value
C_p = Capacitance in parallel with C_v
C_s = Capacitance in series with C_v
BW = Tuning bandwidth, a function of D
d = $\sqrt{D}$, used in the bandwidth equation

A few other specific terms will be defined later.

The desired capacitance ratio, D, may vary slightly from its original value. This depends on the tolerances of C_p or C_s, and whether or not trimmer capacitors are used. The final value of D must be larger than the original D if the desired frequency band is to be covered.

The tuning bandwidth may be checked by the following equation:

$$BW = (d - 1)\sqrt{\frac{f_{max}f_{min}}{d}} \quad (2)$$

Remember that d is the square-root of the final capacitance ratio, D. **Eq. 2** assumes that the resulting tuning band has the same center frequency as the desired band. BW has the same scale as f, so you can use either megahertz or kilohertz. Usage is shown in the examples which follow.

parallel capacitor

$$C_p = \frac{C_v(V - D)}{V(D - 1)} \quad (3)$$

$$D = \frac{V(C_v + C_p)}{VC_p + C_v} \quad (4)$$

Total capacitance, C_t, at the lowest frequency, is $C_v + C_p$ (see **fig. 1**). For example, a 40 - 360 pF variable

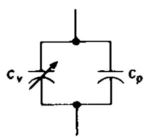

fig. 1. Parallel-capacitor bandspreading circuit. Total capacitance, $C_t = C_v + C_p$.

capacitor is to be used in a vfo to cover the entire 80-meter band. Constants are:

$$D = (4.0/3.5)^2 = (1.143)^2 = 1.306$$

$$V = 360/40 = 9$$

$$C_v = 360\ pF$$

Plugging in the constants,

$$C_p = \frac{360(9 - 1.306)}{9(1.306 - 1)} = \frac{2769.8}{2.7549} = 1005.41$$

A 1000 pF fixed capacitor could be used if the tolerance was 0.5 per cent and no stray capacitance was present in the circuit. A better choice would be to use a fixed capacitor and a trimmer.

Using 5% 680 pF and 220 pF units in parallel, the total capacitance, at maximum tolerance is 945 pF (requiring about 60 pF minimum trimmer and stray capacitance). Total parallel capacitance at minimum tolerance is 855 pF (requiring about 150 pF trim and stray). Without any trimmer, and assuming a stray capacitance of 5 pF, the nominal value of the parallel

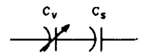

fig. 2. Single series capacitor should be used with care in bandspread circuits because this arrangement does not allow for any stray capacitance.

capacitance, C_p, is 905 pF. Tuning bandwidth is slightly wider and the new value of D is

$$D = \frac{9(360 + 905)}{(9 \cdot 905) + 360} = \frac{11385}{8505} = 1.339$$

The square-root of D is 1.16 = d. Using the tuning bandwidth equation

$$BW = (1.157 - 1.0)\sqrt{\frac{14.0}{1.157}}$$

$$= 0.157 \cdot 3.479 = 0.546\ MHz$$

The resulting bandwidth is less than 10 per cent wider than desired, using the nominal value of C_p.

The maximum tolerance of C_p yields d = 1.150 and BW = 0.524 MHz, while the minimum yields d = 1.164 and BW = 0.570 MHz. These are worst-case conditions and the difference in tuning bandwidths is only 45.28 kHz. Fixed values of C_p could be used with a hand-calibrated dial for the variable capacitor, C_v.

series capacitor

A single series capacitor should be used with care because this arrangement does not allow for stray capacitance across both C_v and C_s. That will be discussed later. Equations for C_s (**fig. 2**) are:

$$C_s = \frac{C_v(D - 1)}{V - D} \quad (5)$$

$$D = \frac{VC_s + C_v}{C_s + C_v} \quad (6)$$

If your calculator does not have a reciprocal function, the combined capacitance of the circuit, C_c, can be calculated from the following:

$$C_c = \frac{C_v(D - 1)}{V - 1} \quad (7)$$

To illustrate, let's use the same 40-360 pF variable capacitor and 80-meter band as before:

$$C_s = \frac{360(1.306 - 1.0)}{9.0 - 1.306} = \frac{110.16}{7.694} = 14.32\ pF$$

A 15 pF fixed capacitor could be used but the tolerance would have to be better than 5 per cent because a low limit value of a 5% capacitor would be 14.3 pF, which is too low. However, parallel connected 5% 10 pF and 5.6 pF units will work with worst-case values of 14.8 and 16.4 pF.

To make certain that the entire band is covered, C_s should be slightly larger than the calculated value. In the parallel situation, C_p should be slightly lower than calculated. Remember these conditions when working with the series-parallel configurations which follow.

The new D value for the nominal 15.6 pF series capacitor is

$$D = \frac{(9.0 \cdot 15.6) + 360}{15.6 + 360} = \frac{500.4}{375.6} = 1.33$$

Tuning bandwidth will be 537.17 kHz for the nominal value of C_s. The maximum combined capacitance is then

$$C_c = \frac{360(1.33 - 1.0)}{9.0 - 1.0} = \frac{119.62}{8} = 14.95\ pF$$

series-parallel configuration

Fig. 3 shows two ways of arranging C_v and C_s in a bandspreading circuit. The arrangement of **fig. 3A** is preferred because strays can be included with the parallel capacitor. The version in **fig. 3B** is useful where the series capacitance is part of a bypass or a feedback divider for a Clapp oscillator. Each version uses the same basic equations already discussed, but with different component notations to prevent any confusion.

Calculation can be done in two ways: either break up the circuit into the basic arrangements and use the equations already given; or solve directly with the equations which follow. In practice the latter process is a bit quicker.

In the series-parallel circuit of **fig. 1A** the component notations are as follows:

C_{pa} = Parallel capacitance
C_{ta} = Total maximum capacitance
C_{cs} = Maximum capacitance of series part only
A = Intermediate capacitance ratio, series part only

All other notations are as before. The A value may be anything at the beginning but *must be between V and D* for the circuit to work. Since C_s is usually a fixed capacitor

$$A = \frac{V\,C_s + C_v}{C_s + C_v} \qquad (8)$$

Then
$$C_{pa} = \frac{C_v\,(A - 1)(A - D)}{A(D - 1)(V - 1)} \qquad (9)$$

$$C_{ta} = \frac{DC_v(A - 1)^2}{A(D - 1)(V - 1)} \qquad (10)$$

Note that the denominators of C_{pa} and C_{ta} are the same. Storing the denominator in the calculator's memory allows a fairly quick calculation of both capacitance values.

In some cases the resonant impedance dictates a certain value of C_{ta}, and C_v is the only other known value. The value of A can be found by letting $C_j = 2DC_v$

$$C_k = C_j + C_{ta}\,(D - 1)(V - 1)$$

then
$$A = \frac{C_k + \sqrt{C_k^{\,2} - C_j^{\,2}}}{C_j} \qquad (11)$$

and
$$C_s = \frac{C_v(A - 1)}{V - 1} \qquad (12)$$

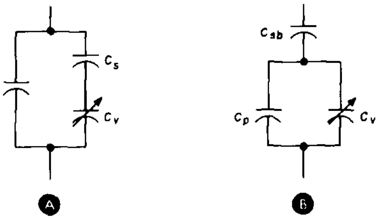

fig. 3. Two basic series-parallel capacitor configurations used in bandspreading circuits. The circuit in (A) is preferred because strays can be included with the parallel capacitor C_{pa}. Arrangement in (B) is often seen in the feedback divider of a Clapp oscillator.

To illustrate, an oscillator is required to cover 5.0 to 5.5 MHz with a 40 to 360 pF variable capacitor. The oscillator tank-circuit requires about 450 pF total at the low-frequency end.

$$D = (5.5/5.0)^2 = 1.21$$
$$V = (360/40) = 9$$
$$C_v = 360\ \text{pF}$$
$$C_{ta} = 450\ \text{pF (approximately)}$$

Solving for the approximate value of A

$$C_j = 2 \times 1.21 \times 360 = 871.2$$
$$C_k = 871.2 + (450[1.21 - 1]\ [9 - 1]) = 1627.2$$
$$C_k^{\,2} - C_j^{\,2} = 2647780 - 758989 = 1888791$$
$$A = \frac{1627.2 + 1374.3}{871.2} = 3.445$$
$$C_s = \frac{360(3.445 - 1)}{9 - 3.445} = \frac{880.3}{5.555} = 158.5\ \text{pF}$$

Therefore, 150 pF is the closest standard value. Using the first equation for A

$$A = \frac{(9 \cdot 150) + 360}{150 + 360} = \frac{1710}{510} = 3.353$$
$$C_{pa} = \frac{360(3.353 - 1)(3.353 - 1.21)}{3.353(1.21 - 1)(9 - 1)}$$
$$= \frac{1815.2}{5.633} = 322.25\ \text{pF}$$
$$(A - 1)^2 = 5.536$$
$$C_{ta} = \frac{1.21 \cdot 360 \cdot 5.536}{5.633} = \frac{2411.5}{5.633}$$
$$= 428.13\ \text{pF}$$

This is very close to the required total tank capacitance. If C_s is a fixed 5% unit, will a fixed value of C_p with the same tolerance work? The lowest value of C_p occurs with C_s low:

$$C_s\ low = 0.95 \cdot 150 = 142.5 \text{ pF}$$

$$A = \frac{(9 \cdot 142.5) + 360}{142.5 + 360} = 3.269$$

$$C_{pa} = 306.18 \text{ pF}$$

$$C_{ta} = 408.27 \text{ pF}$$

The required value of C_{pa} has decreased nearly 5 per cent from the nominal value of 322.25 pF. In order to get the variable's dial to cover as much of the band as possible, a fixed 270 pF capacitor with a parallel trimmer would be a better choice. The trimmer capacitor should have sufficient range to compensate for any tolerances in the 270 pF capacitor as well.

Where fixed capacitors are used for both C_s and C_{pa}, the narrowest bandwidth will occur when C_s is low and C_{pa} is high. The widest bandwidth occurs with C_s high and C_{pa} low. To find D for the bandwidth formula use the following relationship:

$$D = \frac{AC_{ta}}{C_{ta} + C_{pa}(A-1)} \tag{13}$$

In the series-parallel configuration of **fig. 3B** the component notations are:

- C_{sb} = Series capacitance
- C_{tb} = Total maximum capacitance
- C_{pv} = Maximum capacitance of parallel part only
- B = Intermediate capacitance ratio, parallel part only

As with the previous configuration, B must have a value between V and D. Note that there is no compensation for stray capacitance across the total; this arrangement is fine for circuits such as a Clapp oscillator where C_{sb} is the total of the feedback divider network. Then

$$B = \frac{V(C_v + C_p)}{C_v + VC_p} \tag{14}$$

and

$$C_{sb} = \frac{B\,C_v(V-1)(D-1)}{V(B-1)(B-D)} \tag{15}$$

$$C_{tb} = \frac{B\,C_v(V-1)(D-1)}{V(B-1)^2} \tag{16}$$

Most circuits will have a fixed value of C_{sb} so will require a direct solution for the value of C_p. Using temporaries

$$C_q = 4\,VC_v \left[\frac{C_{sb}(V-D)}{D-1} - C_v\right] \tag{17}$$

$$C_r = C_v(V+1) + VC_{sb} \tag{18}$$

then

$$C_p = \frac{\sqrt{C_q + C_r^2} - C_r}{2V} \tag{19}$$

Taking the same oscillator example as before, with the same tuning range of 5.0 - 5.5 MHz and 40 - 360 pF variable, but in a Clapp configuration with two parallel 1000 pF feedback divider capacitors:

$$C_{sb} = 500 \text{ pF}$$

$$D = (5.5/5.0)^2 = 1.21$$

$$V = 360/40 = 9$$

$$C_v = 360 \text{ pF}$$

C_p is found via the temporaries:

$$C_q = 4 \cdot 9 \cdot 360 \left[\frac{500(9.0 - 1.21)}{1.21 - 1} - 360\right] = 2.357 \times 10^8$$

$$C_r = 360(9+1) + (9 \cdot 500) = 8100$$

$$C_q + C_r^2 = (2.357 \times 10^8) + (6.561 \times 10^7) = 3.013 \times 10^8$$

$$C_p = \frac{17358.3 - 8100}{2 \cdot 9} = 514.35 \text{ pF}$$

The inductor must resonate with the total capacitance so the conventional series calculation with C_{pv} = 874.35 pF (360 pF + 514.35 pF) would yield C_{tb} = 318.10 (874.35 pF in series with 500 pF). Solving for B

$$B = \frac{9(360 + 514.35)}{360 + (9 \cdot 514.35)} = 1.577$$

$$C_{tb} = \frac{1.577 \cdot 360(9-1)(1.21-1)}{9(1.577 - 1.0)^2} = 318.31 \text{ pF}$$

The two C_{tb} values differ by less than 0.1 per cent. Checking the worst-case tolerances of C_{sb} will give C_p = 501.55 pF and C_{tb} = 306.19 pF with C_{sb} at the -5% tolerance limit and C_p = 526.70 pF and C_{tb} = 329.76 pF at the +5% limit. Since stray capacitance in a Clapp oscillator tank circuit is primarily across capacitor C_{sb}, it can usually be neglected.

things aren't always what they seem

Fig. 4 illustrates what really occurs in a resonant circuit when the inductor exhibits appreciable distributed capacitance. This is more apt to be the case at lower frequencies where the inductance is large.

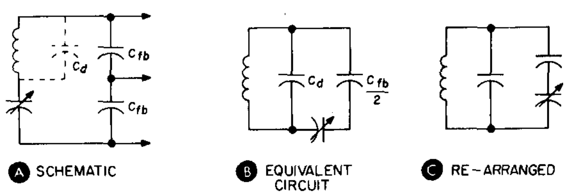

fig. 4. Effect of distributed capacitance which appears across all practical inductors. In the circuit schematic (A), the distributed capacitance is shown as the stray, C_d, across the inductor. This is equivalent to the arrangement in (B) where the feedback capacitors have also been combined into one unit. The re-arranged circuit (C) indicates that the circuit of fig. 3A should be used when making bandspread calculations.

Fig. 4A shows a Clapp oscillator tank as it would be drawn in a schematic. C_d is the distributed capacitance across the inductor. In **fig. 4B** the distributed capacitance is shown and the feedback network is reduced to a single capacitor, $C_{fb}/2$. The equivalent circuit in **fig. 4C**

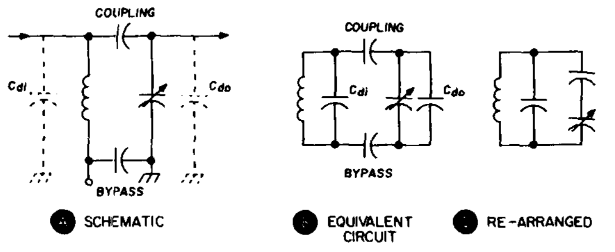

fig. 5. Evolution of a tuned interstage circuit from the schematic (A), to the equivalent circuit (B), to the final configuration in (C) which indicates that the arrangement of fig. 3A should be used when making bandspread calculations.

indicates that the series-parallel circuit of **fig. 3A** should be used when determining capacitor values. Distributed capacitance becomes C_{pa} and the feedback divider becomes C_s.

Fig. 5 shows the transformation of a tuned interstage circuit with a bypass and coupling capacitor plus strays. Redrawn in **fig. 5B**, stray capacitance at the output, C_{do}, appears across the variable, and input strays, C_{di}, are across the inductor. In **fig. 5C** the variable capacitance is modified by the parallel output stray capacitance, and the bypass and coupling capacitors are combined in series with the variable. This fits the configuration of **fig. 3A**.

If you assume that the bypass, coupling, and stray capacitance will not affect tuning, you are wrong. Suppose a 10-50 pF variable capacitor was originally chosen along with 1000 pF coupling and bypass capacitors; strays are 5 pF on each side. Instead of the original capacitance ratio of 5, D is now 2.788, and the tuning bandwidth is only 74.7 per cent!

phase-locked-loop applications

An L-C oscillator with a varactor diode as the tuning element is often used as a voltage-controlled oscillator (vco) in a phase-locked loop because it has better noise characteristics than the emitter-coupled multivibrator type found in many PLL ICs.

The series-parallel circuit of **fig. 3A** applies itself well in this circuit. The varactor or VVC (voltage-variable capacitor) diode is C_v, C_s can be a fixed value, and C_{pa} can be trimmed or be fixed with the inductor trimmed. One caution: To keep the varactor under control of its bias voltage, peak rf voltage across the diode should not exceed the bias voltage. Also, the combined rf peak and bias cannot exceed the breakdown ratings of the diode. The smallest possible value of C_s will prevent these conditions because the rf tank voltage across the diode is reduced by the fraction $C_s \,/\, (C_s + C_v)$. Remember, too, that bias voltage varies inversely to capacitance.

Most inductors have a positive temperature coefficient and most fixed capacitors have zero or negative temperature coefficients. A breadboard oscillator built with fixed, NPO type capacitors (zero temperature coefficient) will help to determine the amount of correction required.

The breadboard should be attached to a fairly large metal or ceramic mass to keep circuit temperatures from changing too rapidly. A casserole dish with a cover is handy for the thermal mass. The freezer compartment of a refrigerator can serve as a "cold soak" chamber. An all-glass thermometer is good enough if the bulb end is mounted near the circuit. A transparent dish cover allows you to see everything; masking tape can be used to seal the openings for the power and output wires. A frequency counter or calibrated receiver is essential for frequency-drift measurements.

Decreasing frequency with increasing temperature means that negative temperature coefficient capacitors must be used to compensate the circuit. The following formula works in this case and where fixed parallel capacitors are used

$$C_{vt} = \frac{C_{tot}\,(D_t - 1)\,10^6}{D_t\,\Delta T_{tc}} \tag{20}$$

Where:

- C_{tot} = total capacitance across the inductor
- C_{vt} = that part of C_{tot} which requires temperature compensation
- D_t = square of the frequency change, greater than one
- ΔT = temperature range of measurement, degrees Celsius
- tc = negative temperature coefficient expressed as parts per million (ppm) per degree C

For example, suppose an oscillator circuit has C_{tot} = 1000 pF, made up largely with fixed NPO values, a 40°C temperature range, and N750 type ceramics are to be used for compensation. Frequency drift is 5.000 to 5.063 MHz. Therefore, the highest to lowest frequency ratio is 1.0126 making D_t = 1.02536.

$$C_{vt} = \frac{1000(1.02522 - 1.0)\,10^6}{1.02536 \cdot 40 \cdot 750}$$

$$= \frac{2.536 \times 10^7}{30760.8} = 824.4 \text{ pF}$$

This is within about 0.5 per cent of the standard value of 820 pF, which would provide acceptable results for most applications. In some cases you may find that, with some trial and error calculations, you can arrive at a combination of fixed compensating capacitors which will do the job.

The casserole dish method will take about three hours for frequency measurements to stabilize, with about the same amount of time required for the cold soak. The dish can be elevated in temperature with a couple of lamps heating the sides of the dish. Turn the lamps off at least ten minutes before making a frequency measurement to allow the "chamber" to stabilize.

For best results, the dish should have opaque sides. Pyrex dishes work all right if a heating pad is substituted for the lamps. The difference in heaters is probably due to infrared heating of the breadboard directly through the transparent Pyrex. It is also possible that the thermometer can be heated more by direct lighting, thus giving a false reading.

measurement of unknown values

A bridge or Q-meter is the obvious choice for measuring unknown capacitance but good accuracy can be achieved with simpler methods. A grid dipper and one standard capacitor will serve as a starter. A standard in the 100 to 200 pF range is acceptable for most work. Arco-ElMenco has a series of 1-percent standards which are an excellent choice.

The dipper method uses a test inductor that resonates with the standard capacitor. The unknown capacitor is then resonated with the test coil and the two frequencies are measured. The unknown capacitor differs from the standard by the square of the resonant frequency ratio. Overall accuracy depends both on the standard capacitor and on the method (and accuracy) of frequency measurement.

Most grid-dipper dials are too coarse for even 5 per cent accuracy. Coupling to the test coil varies and the amount the dipper frequency is "pulled" depends upon how closely the dipper is coupled to the tuned circuit. An all-band receiver can be used to tune in the dipper for better frequency accuracy. Masking tape can be used to hold both the dipper and test coil in position.

If there is metal on or just under your workbench, elevate the grid dipper and the test coil about an inch (2.5cm) on a piece of Masonite or plywood to avoid excess capacitance coupling to the metal. The dipper case should be grounded to the receiver chassis to prevent dipper detuning when changing the position of your hands.

making your own standard capacitor

There are plenty of old 30-365 pF broadcast-band variables in junkboxes. A three-gang variable can be used as a two-range standard variable for 20-243 and 90-1095 pF. A simple schematic is shown in **fig. 6**.

The variable should be insulated, mounted in a metal box, and provided with a good dial. A vernier dial with a numeric scale is fine since the device won't be used daily. Heavy wire, at least number 18 (1.0mm) should be used and the dpdt switch of the slide type for minimum inductance.

Before starting construction, arrange to have access to an accurate bridge for calibration of the finished standard. A Q-meter may be needed for the low range. Q-meters have accurate capacitance and the substitution method is used for calibration. Substitution involves a test coil on the Q-meter inductor terminals with the variable standard connected to the capacitor terminals. The maximum capacitance on the low range is measured on a bridge, the Q-meter capacitance is set at minimum, and peaked with the frequency dial. Calibration is then made by holding frequency constant, moving the Q-meter capacitor to a higher value, then repeaking by lowering the variable standard. The variable's capacitance from maximum is equal to the Q-meter's capacitance difference from its minimum starting point.

distributed capacitance and true inductance

Large inductors have distributed capacitance which is parallel with the inductor. In high-impedance resonant circuits, this may affect tuning. The distributed capacitance also affects true inductance measurements. It should be considered in air-wound coils greater than 50 μH or greater for slug-tuned coils. Both distributed capacitance and true inductance may be determined by using a grid dipper (or Q-meter) and applying the following formulas.

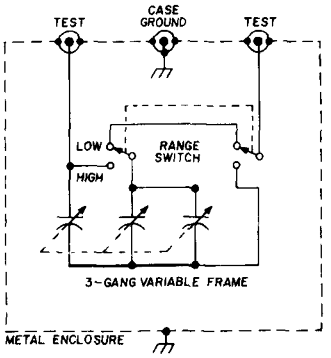

fig. 6. Circuit for building your own standard capacitor using a three-section 365-pF variable. Capacitance is 20-243 pF in the low range, and 90-1095 pF in the high range.

C_2 = maximum standard capacitance, pF, at lower frequency, f_l (MHz)

C_1 = minimum standard capacitance, pF, at higher frequency, f_h (MHz)

C_d = distributed capacitance of inductor, pF

L_t = true inductance, μH

then

$$C_d = \frac{C_2 - 4\,C_1}{3} \;\; pF \qquad (21)$$

With f_h twice the frequency of f_1

then

$$L_t = \frac{18997.7}{f_l^2\;(C_2 - C_1)} \;\; \mu H \qquad (22)$$

summary

Calculate carefully, allow for tolerances, and use short, thick connection leads to reduce stray inductance. The techniques given here will reduce many weekends of "cut and try" to a few hours with paper and pencil. Increased accuracy is an added bonus.

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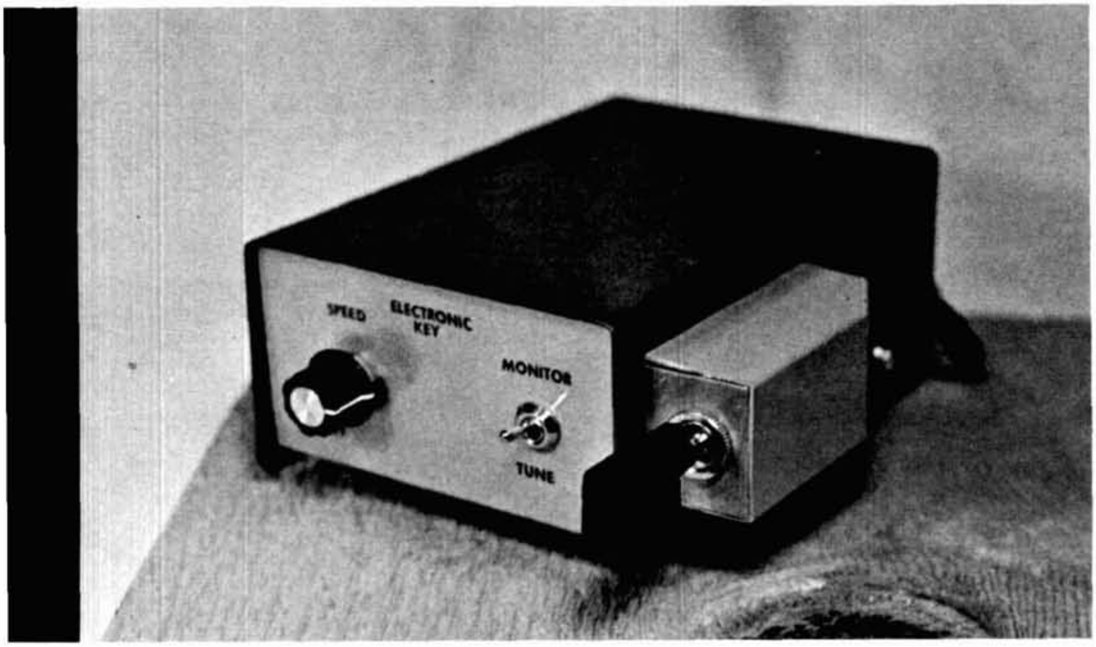


ideas for a portable keyer paddle

Two designs for mechanical input to your electronic keyer — great for portable work

Often the need arises for a small, dependable key to complement a miniature portable electronic keyer for use with QRP transmitters. The keyer electronics can be small, lightweight, and dependable.[1]

Several keyers were designed and either mounted inside the QRP rigs or used outboard. However, the choice of keys to operate the keyers always left something to be desired. Two key designs were developed that are small, lightweight, and dependable. I've named these the *Dip-Key* and the *Lev-Key*. Each uses a different operating principle, but both function well. The *Lev-Key* is particularly rugged and survived a recent trip to a Pacific island while operating QRP portable.

the dip-key

The *Dip-Key* schematic is shown in **fig. 1**. This circuit is basically a miniature touch-operated switch. The switch closure of the output transistor is sufficient to trigger the keyer inputs of cmos keyers. The heart of this design is a 14-pin dual in-line (DIP) wire-wrap socket, which is used for the two key levers. The DIP socket is mounted so that the pins extend out from a small piece of board. For a 14-pin socket, pins 1, 3, 5, 7, 8, 10, 12,

By **Gene Hinkle, WA5KPG**, I/O Engineering, 9503 Gambels Quail, Austin, Texas 78757

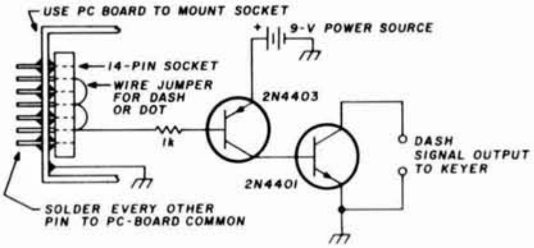
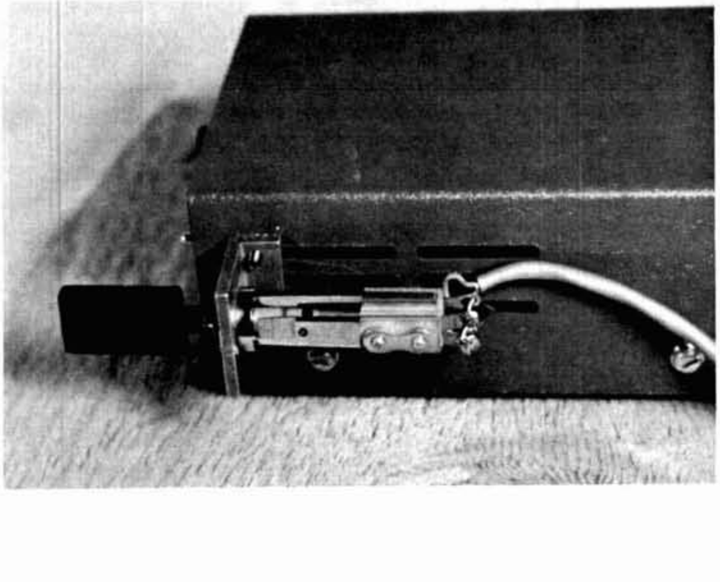


fig. 1. One-half of the DIP-KEY circuit showing use of a 14-pin wire-wrap DIP socket for a paddle. Dash circuit is shown; dot circuit is the same design. Socket is mounted from the inside of a small enclosure with the pins protruding to the front. Battery is mounted with the circuit, or power can be taken from the electronic keyer.

and 14 are soldered to the PC board ground. Pins 2, 4, and 6 are wired together to form the dash paddle, while pins 9, 11, and 13 are connected in parallel to form the dot paddle. Finger-skin resistance between any two adjacent pins creates a switch closure at the output of the respective dot or dash transistor. A small 9-volt battery was used to power the transistor switch, but power may be taken from the keyer power supply.

Features of this design are iambic twin-paddle operation, no moving parts, quiet operation, and extremely small size. The size can be as small as that of one 14-pin socket if the transistor and other components are mounted with the rest of the keyer electronics. The DIP socket is mounted from the inside of the mounting plate, with wire-wrap pins extending forward. Almost any transistor can be substituted for those shown. The only disadvantages to this design are the exposure of the small pins to the elements and the need for a fairly low skin resistance (less than 100k) for reliable switch operation. At times, with very dry fingers, it may not be possible to obtain a reliable switch closure. Normally, however, there seems to be low enough resistance, especially during contest operation!

Side view showing LEV-KEY mounted on the QRP Accu-Keyer.



the lev-key

The *Lev-Key* evolved from the use of pushbuttons as the dot and dash levers for a keyer during portable operation. Pushbuttons are unreliable and difficult to use efficiently. I've discovered, however, that by using a standard switch known as a Switchcraft *Lev-R* switch, a dependable and reliable key can be constructed. The beauty of the *Lev-Key* is that mounting requires just one 0.5-inch (12.5mm) hole. The key is narrow and small. A three-position, spdt normally-open switch was chosen. The center position is *off*. Thus, by moving the switch lever one way or the other, a dot or dash switch closure is achieved. By judicious spacing of the switch contacts travel may be adjusted to individual preferences. This key is easily added to existing keyers or may be built into the rigs themselves.

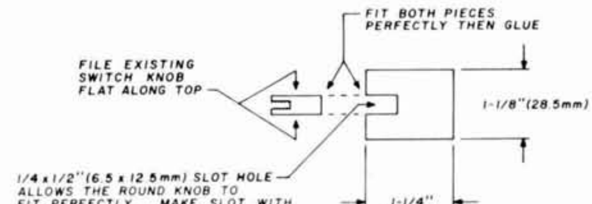


fig. 2. Paddle extension for the LEV-KEY. The paddle, which is made from fiberglass PC-board material, is cemented to the round knob then painted black.

The Switchcraft *Lev-R* switch is identified by the manufacturer's type number 3037 and consists of two sections. The switch lists in the Burstein-Applebee catalog for $3.92, but these switches may also be obtained from surplus equipments and junk boxes. If the *Lev-R* switch is not the spring-return type, a locking type will work by bending the leaf springs slightly so the leaf spring does not cause a locking action. The photos show the method used to mount the *Lev-Key* alongside the QRP Accu-Keyer.[1] Note the small paddle added to the original black plastic knob. **Fig. 2** shows the dimensions for the added paddle. The features of this key are extreme ruggedness, small size, easy mounting, and low cost. The main disadvantage is single-paddle operation, which rules out iambic operation.

Although these designs may not be new, they give some ideas to those who wish to operate portable with minimum size and weight. These designs require only a very small investment for the fellow who would like to have a paddle for his keyer.

reference

1. Gene Hinkle, WA5KPG, "The QRP Accu-Keyer," *QST*, January, 1976, page 24.

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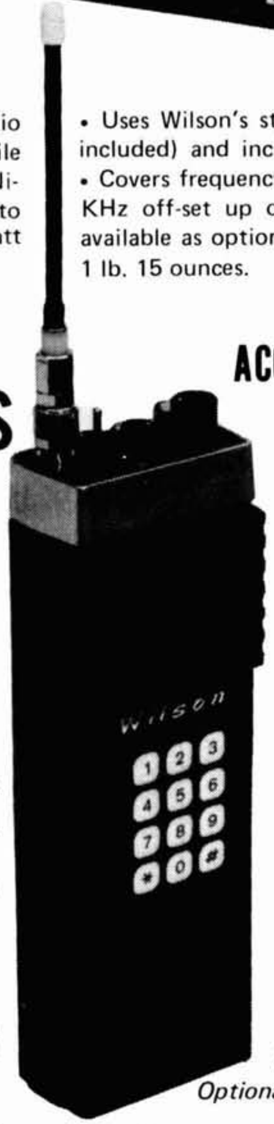

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More Details? CHECK—OFF Page 118

repair bench

Pat Shreve, W8GRG

troubleshooting logic circuits

What is a logic circuit? In its broad sense, the term includes a wide range of devices, from simple analog units such as a volt-ohmmeter to the latest microprocessor. In this discussion I am going to take a narrower view, and will concentrate on troubleshooting methods applicable to simple digital logic circuits and devices using common ICs and discrete components which are likely to be found in amateur radio station equipment and accessories.

understanding logic circuits

When the subject of digital logic and integrated circuits comes up, many amateurs back away with remarks such as, "I used to know quite a bit about vacuum tubes, and I've learned a little about transistors, but this IC stuff is all Greek to me." So let's not back away, but step up and see what sort of circuits are involved. Take for example the 7405 inverter, one of the basic units in the popular TTL (transistor-transistor-logic) line. An IC is commonly called a "chip", and the internal structure of one of the six inverters on this IC chip is shown in **fig. 1**. It consists of three transistors and three resistors, with a reverse-voltage protection diode placed between the input and ground. The transistors and resistors are connected in such a way that when the input is grounded Q1 is turned on and Q2 is turned off; which turns off Q3, and ungrounds the output. When the input is above ground the sequence is reversed and the output is grounded. Note the similarity between this circuit and the 7403 NAND gate shown in **fig. 2**. The only difference is that the 7403 has a second emitter on Q1 to provide a second input. Grounding either input turns Q1 on, so the output is ungrounded unless both inputs are *high*, that is, above ground.

By R. B. Shreve, W8GRG, 2842 Winthrop Road, Shaker Heights, Ohio 44120

Practically all TTL ICs are variations and combinations of these, or similar, gate and inverter circuits. If you can understand them, you can understand TTL logic. This is important, because the key to troubleshooting any logic circuit is understanding how it is supposed to work and what the various components are supposed to do.

troubleshooting tools

Contrary to many amateurs' impressions, you don't need a lot of expensive equipment to analyze and repair most of the logic circuits found in amateur stations, repeater control systems, autopatches, etc. It is true that if you are going to work on high-speed synchronous logic, time factors are important and a dual-trace, high-frequency oscilloscope is a big help, if not a necessity. Most of us are not going to be servicing a computer, however. The logic with which we are concerned either operates slowly enough or can be slowed down enough to permit checking the logic state of inputs and outputs with a simple voltmeter. It doesn't even have to be an expensive meter — one of the nice things about digital logic is that, when operating properly, inputs and outputs are either *high* (close to the 5-volt supply potential) or *low* (close to ground potential). Any in-between voltage is an indication of possible trouble.

At the occasional test point of a timer or counter reset where the logic is supposed to generate a brief pulse, a simple logic probe is useful. The one I use was described in *ham radio*, and the circuit is reproduced in **fig. 3**.[1] It can be built on a PC board or small strip of Vector board and enclosed in any convenient plastic tube. *I used the body of a disposable 20cc plastic syringe* discarded by a local laboratory. One other thing you will need is a manual or individual data sheets on the ICs with which you are working. These are obtainable from the manufacturer or distributor.

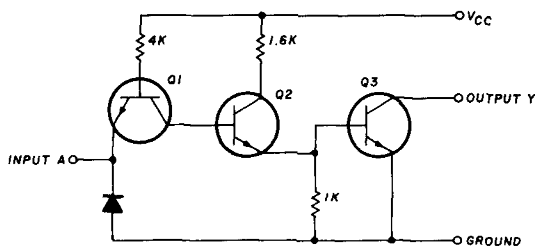

fig. 1. Typical circuit of one of the six inverters in a SN7405 IC. Component values are nominal, not exact.

checking a simple circuit

Let's assume you have assembled your probe. Before you put it in the plastic tube, connect the red wire to the positive (+) terminal, and the black wire to the negative (−) terminal of a 5-volt source. If everything is okay, the LED should light when you apply +5 volts to the input with the switch in the positive position. In either case it should stay lighted until you press the reset button.

Suppose the LED in the probe does not light at all. If you have any doubt about the LED, first test it and its 270-ohm series resistor by applying +5 volts to the resistor after disconnecting it from pins 3 and 4 of the IC. Check with a voltmeter to be sure there is +5 volts at the hot end of the 10k resistor, the 0.01 μF capacitor, and pin 14 of the IC as shown in the diagram. With an ohmmeter, check continuity to the black lead from pin 7 of the IC, the ground end of the capacitor, and the emitter of the transistor.

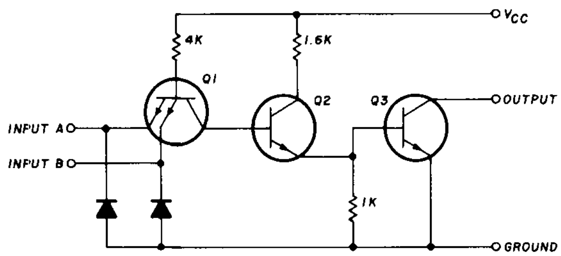

fig. 2. Typical NAND gate; one of four in a SN7403 IC.

Now connect the negative lead of the voltmeter to ground and the positive lead to the junction of the 10k resistor and the transistor collector. It should show zero potential when the input is grounded with the switch in the negative position, and also when the input is at +5 volts with the switch in the positive position. It should show +5 volts when the switch position or input polarity is reversed. If the circuit does not meet both tests, check the 10k and 4.7k resistors with an ohmmeter; if they are both okay, replace the transistor.

If the transistor, LED, and related components all check out, the trouble is in the IC. The simplest thing to do would be to replace it; but for practice, let's check it out. The 7400 gate is just like the 7403 illustrated in **fig. 2** except for an internal source of +5 volts to the output when it is in its *high* or logic 1 state. Thus pin 6 should be *low* when both pins 4 and 5 are *high*, and pin 6 should be *high* if either pin 4 or 5 is *low*. Pin 3 should be *low* when both 1 and 2 are *high*, and it should be *high* if either input is *low*. Connect the negative test lead of the voltmeter to ground and the positive lead to the junction of pins 6 and 2. Press the reset button. The meter should show more than +2.5 volts (typically 4 volts or more) when the button is pressed. It should stay at this level when the button is released until the input is grounded with the probe switch in the negative position or connected to V+ with the probe switch in the positive position. When either of these input conditions occurs the meter reading should drop to less than 0.5 volt. The LED should also light. If the circuit fails any of these tests, try a new IC.

testing a more complex circuit

As an example of how to test a more elaborate system, consider the circuit shown in **fig. 4**. It is the access control device used on the Lake Erie Amateur Radio Association 16/76 repeater in Cleveland, Ohio, which I described in an earlier article.[2] It is a good circuit to illustrate troubleshooting procedures because it contains a timer, two counters, NAND and NOR gates, and some discrete components — all on one circuit board.

First, let's look at what the circuit is supposed to do when it is operating normally. If there is no outside interference on the input frequency, the control unit permits the repeater to run *open*, i.e., carrier access without an access tone. The receiver COR (carrier operated relay) pulse is shaped by the 7400 gates U5A and U5B, and keys the transmitter through U5C as long as the output of U5D is *high*. Note that turning the guard control switch *off* latches the output of U5D *high* and lets the repeater run open regardless of what is happening in the rest of the unit.

If the control switch is *on*, the output of U5D is controlled by U1. This is a 7490 decade counter which is really two counters: one that divides by two and one that divides by five. For either to count, pin 2 or pin 3 and, at the same time, pin 6 or pin 7 must be *low* (grounded). (Remember, TTL logic sees unconnected inputs as *high*). With proper input conditions, each cycle of the COR registers one count on the divide-by-five counter. Pin 9 goes *high* on the first count, pin 8 on the second, both 8 and 9 on the third, and pin 11 on the fourth. On the fourth count U1 latches with pins 11 and 12 *high* until the counter is reset. When latched with the control switch *on*, U1 prevents keying of the transmitter by the COR. Resetting is accomplished either by a signal with an access tone through one of the diode inputs, the discrete components, and the U2 NOR gates; or by the

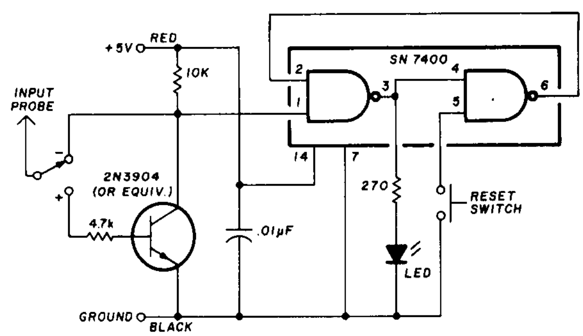

fig. 3. Simple logic probe. Parts arrangement is not critical. See reference 1 for typical layout.

timer circuit of U3 and U4, which also works through the gates.

To illustrate the troubleshooting procedure, let's consider three possible outward signs of a malfunction: failure to guard the repeater by cutting off the keying circuit in the event of repeated interference, failure to respond to an access tone, and failure to revert to carrier access at the end of the interval for which the timer is set. The pulse-shaping and keying circuits of U5 are similar to the logic probe circuit analyzed earlier, so let's assume that those circuits are working as they should.

If the system does not go into the guard mode after being keyed by four successive signals without an access tone, U1 is probably not counting the way it should. This could be caused by a defect in the counter IC, U1, or by an improper signal from some other part of the circuit. Failure to reset could also be due to U1, or due to one of the gates or some other part of the circuit. Since everything comes together at U1, it is a good place to start looking for trouble.

checking the counter

Before doing any testing it is a good idea to disconnect the inputs from the receiver so your checking won't be disrupted by someone keying the repeater. Check the supply voltages with a meter to be sure there is +5 and +12 volts at the power connections to the circuit board and the indicated pins 8, 9, 11, and 12 of U1. All should have less that 0.5 volts or should go to that level when pin 7 is grounded. If they don't, take a reading at pin 3 while pin 7 is grounded. U2B is connected as an inverter between pins 7 and 3 of U1, and pin 3 should be high when pin 7 is low. If it isn't, replace U2. If it is, and the voltage at any of the output pins is still above 0.5 volts, U1 is bad and should be replaced.

To check how U1 counts, you should start with all the outputs and pin 3 *low*, pin 7 *high*. Drive pin 1 *high* by momentarily grounding pin 1 of U5A. Then touch pin 1 of U1 with a grounded probe. Pin 9 should go *high*. Touch pin 1 again; pin 9 should go *low* and pin 8 should go *high*. Both should be *high* after the next pulse, and pin 11 should go *high* on the fourth pulse. When pin 11 goes *high*, so does pin 6. With both pins 6 and 7 *high* the counter should latch, with highs at pins 11 and 12, and *lows* at pins 8 and 9. Additional pulses applied to pin 1 should have no effect on the outputs. If it doesn't latch, check pin 7; if pin 7 is high and pin 12 is not, replace U1.

Pin 10 on U2C controls pin 7 on U1 and pins 5 and 6 on U2B. It should be high unless either pin 8 or pin 9 (the U2C inputs) is *high*. Pin 9 should be *low* at all times except for a momentary pulse when the timer resets. If pin 9 shows a continuous *high* there is trouble in the timer. If pin 9 is low, check the voltage at pin 10 when you ground pin 8. Pin 10 should go *high* when pin 8 is *low*, and vice versa. If it doesn't, replace U2.

Pin 8 should be *low* except when a signal with an access tone generates a *low* at input CR1 or a *high* at CR2. If it is not, there is trouble with U2D or in the discrete component circuitry. Check the voltage at pin 13 of U2 when you ground pin 11 or 12. If pin 13 doesn't go *high*, U2 is bad. If pin 13 stays *high* all the time, check pins 11 and 12. If pins 11 and 12 are also *high* replace U2. If pins 11 and 12 stay *low* there is trouble in the transistor circuit.

Continental Specialties Logic Monitor LM-1 facilitates checking digital ICs and associated circuits. Priced at $84.95 from Continental Specialties Corporation, 44 Kendall Street, Box 1942, New Haven, Connecticut 06509.

checking discrete components

The reset circuit composed of CR1, CR2, Q1, Q2, and the associated resistors is intended to reset U1 by grounding pins 11 and 12 of U2 when a ground pulse is sensed at CR1 or +12 volts at CR2. With neither of these signals present, the voltage at the collector of Q2 should be approximately +5 volts. If it isn't, try grounding the base of Q2. If the collector voltage goes to +5 volts, Q2 and the 22k and 33k resistors are okay. If it doesn't, check each resistor. If they are the correct values, replace Q2.

With the input to CR1 ungrounded, Q1 should not conduct. Assuming the 12-volt supply (V+) is approximately right, the voltage at the junction of CR1 and the three resistors should be about 11 volts, and the voltage at the emitter of Q1 should be about 7.6 volts. There should be practically no voltage at the collector of Q1. If the first two voltages are about right, and there is significant voltage at the collector, Q1 is probably shorted and must be replaced.

The foregoing checks should have identified and corrected the reason for any failure of the control unit to guard the repeater, and should have identified most of the possible causes of control unit failure to respond to an access tone. If a signal with the correct tone still fails to open the guard circuit, apply +12 volts to the input of CR2. The voltage at the collector of Q2 should drop almost to zero. If it does not, CR2 could be failing to conduct, the 1k resistor could be shorted or there could be an open 4.7k resistor in the base circuit of Q2. These components can be checked individually.

If +12 volts at CR2 opens the guard circuit, but a ground at CR1 does not, try grounding the junction between CR1 and the 2.2k resistor. If this opens the guard circuit, replace CR1. If it does not, ground the base of Q1 through an external 2.2k resistor. If this opens the guard circuit, replace the 2.2k resistor on the board. If it doesn't, Q1 is probably open and should be replaced.

checking the timer

As previously mentioned, pin 9 of U2 is supposed to be *low* except for a brief pulse every 15 minutes when the timer resets. You can detect this pulse with the logic probe if you want to wait for it, but there are faster checks. Like U1, U3 is a 7490 decade counter. For it to count the pulses at its pin 14 input, it must have a *low* at pin 6 or 7 and at pin 2 or 3. Pins 6 and 7 are grounded, but pin 2 should be checked. If it is *high* go back and check U2 to see what is keeping it that way.

With pin 2 *low*, you can tap the junction between pin 14 of U3 and the 2.2k resistor with a grounded probe, and check the outputs of U3 with the logic probe or a voltmeter. Pin 12 should change from *low* to *high* or *high* to *low* every time you pulse pin 14. Pin 9 should change on every other pulse, pin 8 half that often, and pin 11 should go *high* on the eighth count. This last output can best be checked with the logic probe, as a *high* at pin 11 drives pin 10 of U2 *low* and pin 4 *high*. The resulting *high* at pin 2 of U3 will reset all its outputs, including pin 11, to the *low* state too fast for a meter to detect the momentary *high* at pin 11.

When you are satisfied with the operation of U3, move on to U4. Using an 8038 as a timer is not an economical way to do the job unless, as I did, you just happen to have one around. An NE555 is less expensive. You can connect your meter to the positive side of the 100 μF capacitor and watch the voltage rise and fall slowly as the timer cycles. Every time it changes direction the output at pin 9 should change state from *low* to *high* or back to *low*. If you don't see this action, test the 100 μF capacitor and the 47k and 100 ohm resistors. If they are all good, replace the IC.

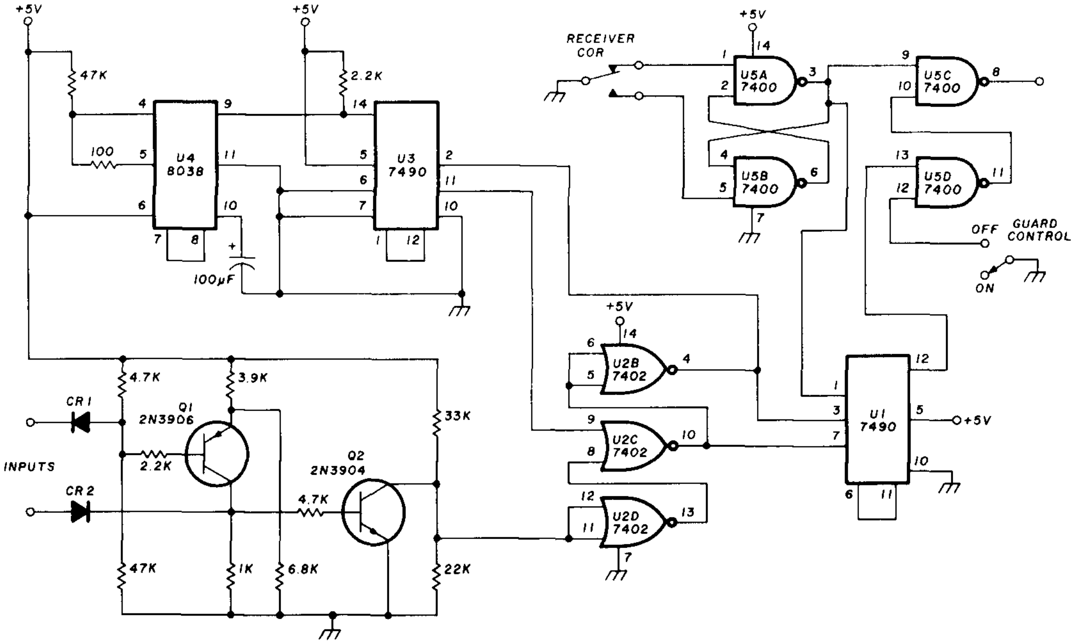

fig. 4. Circuit diagram of a logic system used for repeater access control; a good example of the type of logic circuit found in many amateur installations. IC U2A is not used in this circuit.

conclusion

If you have followed and understood each step of the testing procedure outlined here, you should have a pretty good idea of how to troubleshoot most logic circuits, even without elaborate test equipment. To summarize:

1. Review the data sheets on the ICs involved to be sure you know how each one should perform and how they affect each other.
2. Start at a point where you recognize a malfunction (usually an output), and work back to the source, step by step.
3. If you come to a point where the trail back to the input branches, temporarily disregard one branch and check out the other.
4. When you are satisfied that each component, or group of components, is responding to signals the way it should, mark it okay and go on to the next in line. When you finish a branch, go back and pick up the next one.

references

1. Bill Rossman, "Logic Test Probe," *ham radio*, February, 1973, page 56.
2. R. B. Shreve, W8GRG, "Automatically Controlled Access to Open Repeaters," *ham radio*, March, 1974, page 22.

ham radio

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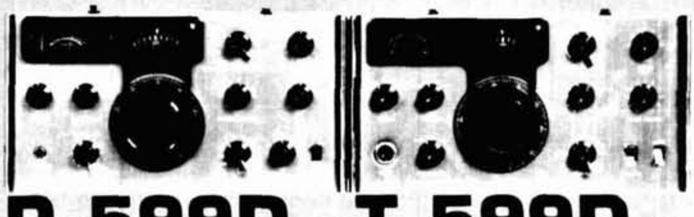
DIMENSIONS: 13.1" W x 5.9" H x 13.2" D
WEIGHT: 35.2 lbs.



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Good audio quality. **W5ZBC** — The most outstanding rig I have ever used. **K8CJQ** — Excellent rig, Good filters. **W7BKK** — Very happy . . . getting excellent quality reports. **W2CET** — Power-signal reports good. **WB2UEH** — I like the compactness and appearance. **VE3IBK** — An excellent rig with superior receiving quality. **K4IVM** — I think it is tops. **WA4LOG** — I've become so used to dip, peak and adjust, this TRITON is a beautiful new experience. **KL7IHW** — Easy to set up—works great. **K4JXD** — Seems to be very FB rig. **WA7KHE** — Fantastic performance. Thanks for a fine rig. **WB4BPG** — No problems—fine rig. **VEIBZ** — Good work. **W9HQT** — Receiver better than expected, CW break-in is super. **W0AP** — Tremendous transceiver. I appreciate your engineering. **WA2ZRO** — Wonderful. **K0SFV** — Real nice rig. You thought of almost every feature and built it in. **KQ9DQ** — Beautiful. **WB0JIQ** — Beautiful radio; however, your ads do not do justice to the radio. **WN5SOH** — Very sophisticated—Easiest tuning rig ever. Very glad I bought it. **K3OJV** — Very impressed. **W4LZP** — Very good results. Put out 100 watts as good as 300 watt rigs. **WA4DQY** — I think the TRITON IV is great. **W6QXN** — Appreciate full CW break-in. **W0INH** — Enjoy light weight. **VE3CYK** — I am extremely pleased with the clarity of receiver and after putting rig on the air, received unsolicited compliments on the audio quality of the transmitter. **K4PHY** — Was 3rd in USA, first in fourth district in WWCQ contest. **W8RYU** — Own Argonaut. Both fine rigs. **W4CDA** — Compact, light weight, good engineering. **WB2WZG** — TRITON IV is the most versitile CW/SSB radio I have ever used. **WB2FMV** — Outstanding. Highly pleased with performance. **WA8ACZ** — A real nice rig. I have owned about every other make. **W5EGK** — Works nicely. **WB4ECO** — I tried this rig, a pleasure to operate. **WA4YRK** — Excellent reports on audio. **WB8NKB** — Wonderful. **W9QPQ** — An excellent rig. Love it. **W8SOP** — Makes running SSB nets a real breeze. Also good on CW nets. **WL7IRT** — Fantastic rig. **W4MDB** — Has rekindled my interest and enthusiasm in Amateur Radio to an extent I hadn't thought possible. It far out distances any competitive product at **any** price. **W6EYR** — Very nice. Been a ham for 45 years and now solid state perfection. **W2RPH** — Excellent rig. **WN0TDK** — TRITON IV is a fabulous piece of equipment. **W5VIW** — Very nice rig **WB2LQF** — Wow! **W9JCV** — Tnx for giving us a FB piece of equipment made in the USA. **W8GHO** — Very pleased. **K4KXB** — Seems to have everything desired. **W4SZ** — A pleasure to operate. **W2FKF** — Greatest rig I ever had. So far in a month 34 QSO's without one miss. Been a ham since 1922. **W4GVC** — Nothing but complements. **WB9EZE** — Well pleased with performance and simplicity of operation. **K4ETI** — Rig is great. **W8CNV** — Man—! what a rig. I've had this call since 1929. Never saw anything like it and I've seen them all! **WB2MZU** — Seems like everything the S - - - - - O - - was supposed to be at one third the price. **WN0VHE** — I think it is a very good rig. **WB9FTD** — Break-in CW is very impressive. **K0CBA** — I believe it is one of the finest HF transceivers on the market. I can't tell you how pleased I am with the noise blanker. I can get on the air from my home station again for the first time in a few years. Other rigs with noise blankers just didn't hack it. **WA7YHW** — I am very pleased with this equipment. It is certainly of high quality. **W7IIA** — Excellent equipment. **WB0RWA** — Couldn't be more pleased with it. It certainly has performed beautifully and is all I expected and more. **WB4QJT** — Like it very much — keep up the good work. **WN1YVX** — Really impressed with looks and performance. **W0NC** — Very FB rig. Performs up to specifications, an excellent design. **K8PBZ** — Already have TRITON II and IV. **W7KD** — This little "T-4" is smooth as silk . . . I've received some very flattering reports about transmitter voice quality and the CW operation is the greatest. **WN8TTO** — I found that the TRITON IV was the best rig on the market for around $800. I love it! **W2JBK** — It is absolutely fantastic. **W8FEI** — Am amazed at receiver performance. I thought I had a top notch receiver with the H - - - - - - - -! **W1FYM** — Your guarantee is refreshingly proper. **W8MOK** — Sure makes a guy look twice at his old tube type gear. **W1TFS** — Finest CW ever, CW selectivity very good. **WB6IVR** — Very satisfied with TRITON IV. Just what I was looking for to use on my yacht. Thanks. **WA8ONP** — Also have a TRITON II. I am pleased that Al Kahn and the **good guys** at TEN-TEC thought of the CW operator! **W2EMX** — Excellent Amateur gear meets and exceeds advertised claims. **W0AMJ** — It looks like there is nothing left to be desired. It is beautiful. **W6SE** — The receive function is outstanding. It is superb in transmit. **W1BV** — In love with this fantastic gem. It's so easy and a pleasure to operate. **W6ASH** — Very happy with performance. Particularly impressed with full break-in and light weight. **WA0IMS** — By far the best rig I have ever operated. I am glad I decided on the TRITON IV and not one of the other transceivers on the market. **WA8HQO** — Thank you gentlemen.

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MICROPROCESSORS

microcomputer interfacing: internal registers within the 8080 chip

In this and several subsequent columns, we will introduce you to additional details concerning the operations of an 8080A-based microcomputer that are controlled by software. It is the software instructions, or steps, that actually indicate to the microcomputer the tasks it must perform. Just as you may start the day with a list of things to be done and a sequence in which they should be accomplished, the microcomputer too, must be provided with a sequential list of program steps. This is called *software*.

In general, you may not be familiar with what each microcomputer instruction does within the microprocessor chip. This should not deter you, however, from using them all in all of your programs. Many of you are not familiar with the inner workings of an internal combustion engine, an automatic transmission, or a Xerox machine; you lack of knowledge does not prevent you from using them daily.

All of our programs are stored in fast-semiconductor memory, either read-write memory or programmable read-only memory (PROM).[1] The microprocessor chip *fetches* an instruction byte from the memory and then executes it within the chip. Each software instruction requires at least one fetch and execute action. Software instructions that contain several instruction bytes require two or three sequential fetch and execute actions. Again, exactly what is done within the microprocessor chip is not of interest, only the overall effect. All software is executed sequentially, one step after another, unless we purposely transfer control to instruction bytes located elsewhere in memory.

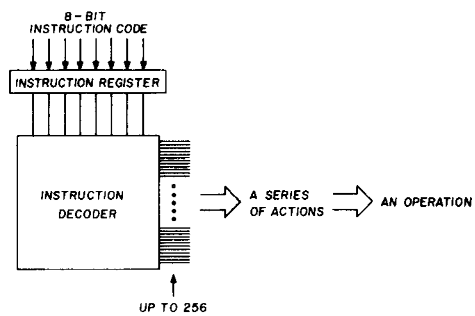


fig. 1. The 8-bit instruction code is stored in the instruction register, where it is decoded into a series of actions that together comprise a microcomputer operation.

In order to conveniently handle the large number of software instructions in the 8080A microprocessor instruction set, it is customary to order them into several instruction groups. The Intel 8080 User's Manual subdivides the instruction set into five groups:

By Peter R. Rony, Jonathan Titus, and David G. Larsen, WB4HYJ

Mr. Larsen, Department of Chemistry, and Dr. Rony, Department of Chemical Engineering, are with the Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Mr. Jonathan Titus is President of Tychon, Inc., Blacksburg, Virginia.

1. **Data Transfer Group.** Move data between registers or between memory and registers.
2. **Arithmetic Group.** Add, subtract, increment or decrement data in registers or in memory.
3. **Logical Group.** AND, OR, EXCLUSIVE-OR, compare, rotate or complement data in registers or in memory.
4. **Branch Group.** Conditional and unconditional jump instructions, subroutine call instructions and return instructions.
5. **Stack, I/O and Machine Control Group.** Includes I/O instructions, as well as instructions for maintaining the stack and internal control flags.

registers

Before we can make sense of these instructions, we must know more about the internal architecture within the 8080 chip itself. We shall present such information in steps, since it can be overwhelming if tackled all at once.

Shown in **fig. 1** is a schematic diagram that depicts the significant aspects of the internal architecture within an 8080 or 8080A* chip. Our emphasis in the diagram has been on accessible 8-bit and 16-bit *registers* that store information within the chip. You should exclude from consideration the Data Bus Buffer/Latch and the Address Buffer, which we show here to make the point that these are the internal circuits that interface the internal digital circuitry with the outside world, *i.e.*, the 8-bit *bidirectional data bus* and the 16-bit *address bus.* As you learn about 8080 microcomputer programs, you will be specially interested in the *accumulator, flags, program counter, stack pointer,* and *general purpose registers* B, C, D, E, H, and L.

We will not say much about the *instruction register,* since its function is automatic and we have little control over it. The function of the instruction register can be best understood with the aid of **fig. 2** which indicates that it is the 8-bit register that temporarily stores the 8-bit instruction code for an instruction that is to be executed. Within the microprocessor chip, an instruction decoder converts the instruction code into a series of actions that together cause a microcomputer operation to occur. The individual actions are clocked by the ϕ_1 and ϕ_2 signals that are input at pins 22 and 15, respectively, on the 8080 chip.

The general purpose registers B, C, D, E, H, and L are used for many varied purposes, *e.g.*, the storage of an 8-bit constant, the storage of a 16-bit pointer address, the storage of an intermediate result in an addition or subtraction, etc. Each general purpose register is eight bits wide and can exchange data directly with the 8-bit external bidirectional data bus. Simple 8080 instructions permit you to transfer eight bits of data from one register to another, from a pair of registers to the program counter, from a register to the accumulator, and from a register to a memory location, and *vice versa.* You can use the contents of a register to perform addition, subtraction, AND, OR, EXCLUSIVE-OR, and compare operations with the contents of the accumulator. The contents or each register can be incremented or decremented. Register pairs, such as register H and register L, can be incremented or decremented as a 16-bit word.

The accumulator also acts as a general purpose register, but it has some special characteristics not possessed by the other six registers. The result of any arithmetic or logical operation is stored in the 8-bit accumulator. The I/O instructions IN and OUT transfer data only between the accumulator and external I/O devices. The contents of the accumulator can be transferred to any other general purpose register or to a memory location, and *vice versa.*

The five flags (zero, carry, parity, sign, and auxiliary carry) are flip-flops that indicate certain conditions have arisen during the course of an arithmetic or logical instruction. Such flags are used by the microcomputer in making decisions, *i.e.*, with conditional jump, call, and return instructions, in multiple-precision arithmetic operations, and in logical masking operations.

The program counter is a 16-bit register in the 8080 microprocessor chip that contains the address of the next instruction byte that must be executed in a program. You can load the program counter register either from a register pair or, more likely from two instruction bytes located sequentially in memory.

The stack is a region of memory that you allocate for the storage of temporary information, usually the con-

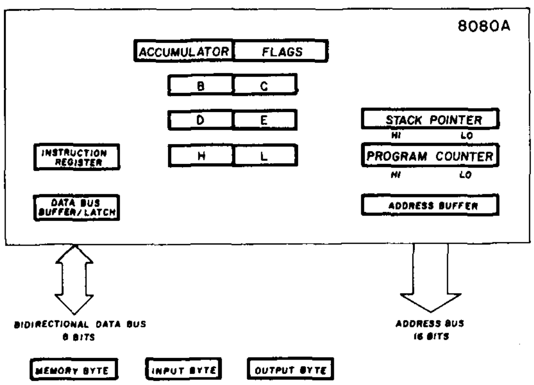


fig. 2. The internal register architecture within an 8080A microprocessor chip. Temporary registers over which you have no direct control have been omitted.

*The 8080A chip is an improved version of the 8080 chip. Both have identical instruction sets and pin outs. As one difference, the 8080A has improved fan-out capabilities.

tents of the internal registers within the 8080 chip. The stack pointer is a 16-bit register that contains the address of the last byte placed on the stack.

This summarizes our brief discussion of the architecture in a typical 8080 microprocessor chip (**table 1**). Keep in mind that there are seven 8-bit registers, two-

table 1. Functions and registers within the 8080A microprocessor.

Accumulator	The register within a computer where the results of all arithmetic and logical operations are placed.
Address bus	A unidirectional bus over which digital information appears to identify either a particular memory location or a particular I/O device.
Bidirectional data bus	A data bus in which digital information can be transferred in either direction. With reference to an 8080A-based microcomputer, the bidirectional data path by which data is transferred between the microprocessor chip, memory, and input-output devices.
Fetch	In a computer, the collective actions of acquiring a memory address and then an instruction or data byte from memory.
Flag	A single flip-flop that indicates that a certain condition has arisen as, for example, during the course of an arithmetic or logical operation in a computer program.
General purpose registers	In the 8080 microprocessor chip, the 8-bit B, C, D, E, H, and L registers.
Program counter	In a computer, the register that contains the address of the next instruction byte that must be executed in a computer program.
Register	A short-term digital electronic storage circuit the capacity of which is usually one computer word or byte.
Software	The totality of programs and routines used to extend the capabilities of computers. Examples include compilers, assemblers, narrators, routines, and subroutines.
Stack	A region of memory that stores temporary information, usually the contents of the internal registers within a microprocessor chip.
Stack pointer	A register that contains the address of the last byte that has been placed on the stack in an 8080 microcomputer.

16-bit registers, and five flags *the contents of which you can control using software*. Much of what an 8080 microcomputer does is to move 8-bytes from one location to another. This will become more apparent in subsequent columns.

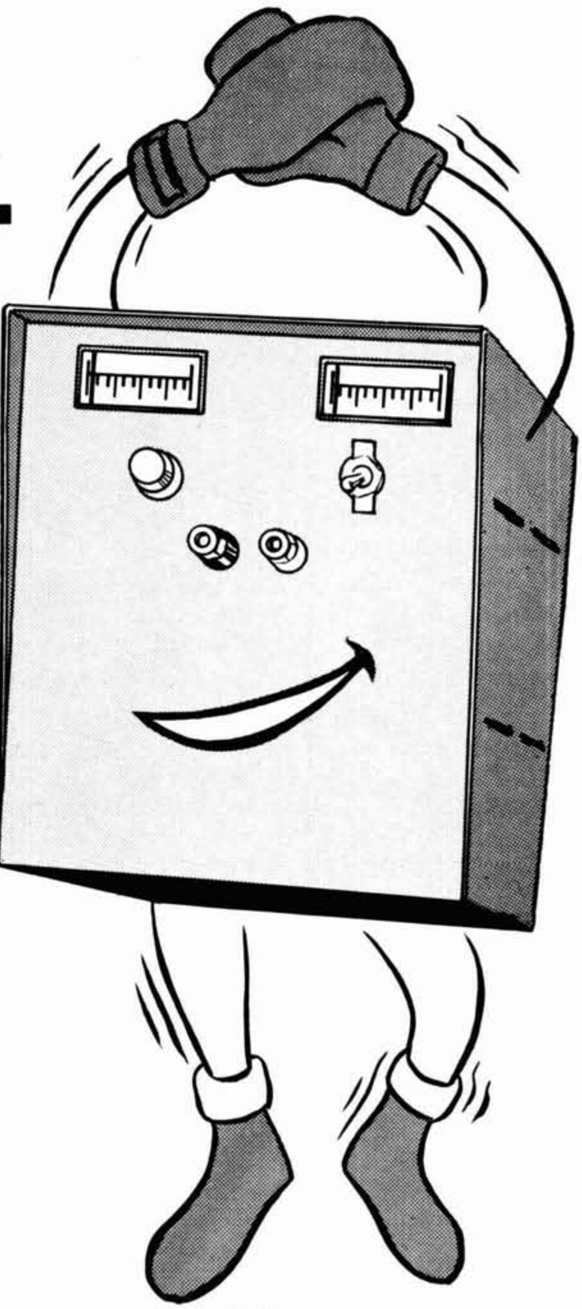
references

1. David G. Larsen, Peter R. Rony, Jonathan A. Titus, "The Structure of a Microcomputer," *American Laboratory*, October, 1975, page 111.
2. *Intel 8080 Microcomputer Systems User's Manual*, Intel Corporation, Santa Clara, California, September, 1975.

ham radio

More Details? CHECK–OFF Page 118

THE Vhf engineering HEAVYWEIGHT



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More Details? CHECK–OFF Page 118

LC circuit calculations

Table lookup for determining resonant frequency in terms of LC ratios

The resonant frequency of an LC circuit may be calculated from

$$f = \frac{1}{2\pi\sqrt{LC}} \tag{1}$$

where L is in henries,
C in farads, and
f in hertz.

An approximate solution is sufficient in many cases, since errors may be present in the form of stray capacitance and self-inductance. Besides, the precise value of a coil or capacitor is seldom known anyway.

Presented here are some aids for solving the problem by using a simple table that allows you to determine resonant frequency in terms of LC products. Also included is a formula for finding inductance in microhenries of air-wound coils when coil diameter and number of turns are known.

An approximate solution may be obtained from an L, C, f, logarithmic graph. However, the L and C decades may list only values 1, 5, 10, 50, etc.; and the f decades may be labeled only at 1, 2, 4, 7, 10, for example. Interpolating a log scale may be tricky, and any three-variable graph may be confusing.

table 1. Basic data for determining LC products as a function of frequency.

f	$L \times C$	f	$L \times C$	f	$L \times C$	f	$L \times C$
0.5	100,000	5	1000	50	10	500	0.1
0.6	70,000	6	700	60	7	600	0.07
0.8	40,000	8	400	80	4	800	0.04
1.0	25,000	10	250	100	2.5	1000	0.025
1.3	15,000	13	150	130	1.5	1300	0.015
1.7	9,000	17	90	170	0.9	1700	0.009
2.0	6,300	20	63	200	0.63	2000	0.0063
2.5	4,000	25	40	250	0.4	2500	0.004
3.0	2,800	30	28	300	0.28	3000	0.0028
4.0	1,600	40	16	400	0.16	4000	0.0016

examples

A simpler method is illustrated in **table 1**. Here f is related to the product ($L \times C$). As an example, consider a circuit with 5 μH and 8 pF. The product (40) indicates a resonant frequency of 25 MHz. It's that easy. Try 15 μH combined with 20 pF. The product (300) gives 9 MHz. (Note: a *larger* product corresponds to a *lower* frequency).

Table 1 works for MHz, μH, and pF but is not limited to these alone. It is also valid for kHz, mH, and nf, where $1\ nf = \mu F/1000$. Likewise it is valid for Hz, H, and μF (refer to **table 2**).

Here's another example: 500 μH x 250 pF. The product (125,000) shows about 0.45 MHz. Or you may simplify by writing 0.5 mH and 0.25 nf. The new product (0.125) corresponds to about 450 kHz. The table may be extended in either direction. You may multiply (or divide) $f \times 10$ when you multiply (or divide) the $L \times C$ by 100.

Let's use the table in reverse. We want a circuit to tune to 1000 Hz using an 88-mH coil. The LC product

By **I. Queen, W2OUX**, 228 East 91 Street, Brooklyn, New York 11212

table 2. Factors for using table with various units of frequency, capacitance, and inductance.

f	$L \times C$
Hz	H x μF
kHz	mH x mμF
MHz	μH x pF

Note: 1 mμF = $\frac{\mu F}{1000}$

(table 1) is 0.025 and L is 0.088 H. The answer is 0.025/0.088 = 0.28 μF.

determining inductances

The value of a capacitor is often known. If it is fixed, it probably has a color code or is labeled. A variable capacitor is known by the number of plates and size. A slug-tuned coil is specified as to maximum and minimum inductance values, but an air-wound single-layer coil is more mysterious. Its approximate inductance may be obtained from the formula

$$\mu H = \frac{D^2N^2}{18D + 40L} \qquad (2)$$

where N is number of turns,
D is diameter, and
L is length (both in inches).

For example, what is the inductance of 24 turns, 0.75 inch in diameter, and 1.5 inch long?

$$L = \frac{(0.75^2)\ (24^2)}{(18 \cdot 0.75) + (40 \cdot 1.5)} = \frac{324}{13.5 + 60}$$
$$\approx 4.4\ \mu H$$

table 3. Some examples of inductances of air-wound coils based on eq. 2.

diameter, inch(mm)	turns, inch.(mm)	length, inch(mm)	μH
0.5 (12.5)	8 (204)	2.0 (51)	0.72
1.0 (25.5)	8 (204)	3.0 (77)	4.20
2.0 (51)	8 (204)	5.0 (128)	27.0

If the dimensions of the coil are given in millimeters, the approximate inductance in microhenries can be found from the following formula:

$$\mu H = \frac{D^2N^2}{460D + 1000L}$$

where N is the number of turns,
D is the diameter, and
L is the length (both in millimeters).

For example, what is the inductance of 24 turns, 19mm in diameter, and 38 mm long?

$$L = \frac{(19^2)(24^2)}{(460 \cdot 19) + (1000 \cdot 38)} = \frac{207936}{8740 + 38000}$$
$$\approx 4.4\ \mu H$$

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integrated-circuit tone generator

The new Mostek MK5085/6 IC can be applied to many different applications, most of which are usable by amateurs. The most interesting application though, is that it can be mated with a keyboard to form an inexpensive *Touch-Tone* generator. This chip will produce tones that are within 0.75% of the required frequency.

The circuit shown in **fig. 1** requires a minimum of parts, all of which are readily available from local sources. A convenient feature of this IC is that it uses the standard 3.579545-MHz television color-burst crystal. These are low-cost crystals and even in this relatively remote area of northern Maine a call to a local television repair shop produced the crystal within an hour. This is much easier and cheaper than trying to purchase a 1-MHz crystal for other tone generators.

On the pin-out diagram (**fig. 2**), pin 15 is for invalid tone select. The pin would be grounded to provide dual tones only. This means that if a single tone condition is created (two keys in the same row or column selected) there would not be an output. Pin 10, mute switch, provides an output when a keyboard entry has been made. The transmitter switch output, pin 15, normally has a voltage present. During the times that keys are depressed, the voltage is removed. The mute switch can be used to key the PTT as shown in **fig. 1**. The capacitor across the relay will keep it pulled in for approximately 2 seconds. Output (pin 16) is from the open emitter of a transistor. A load resistor, normally 1000 ohms, must be connected externally.

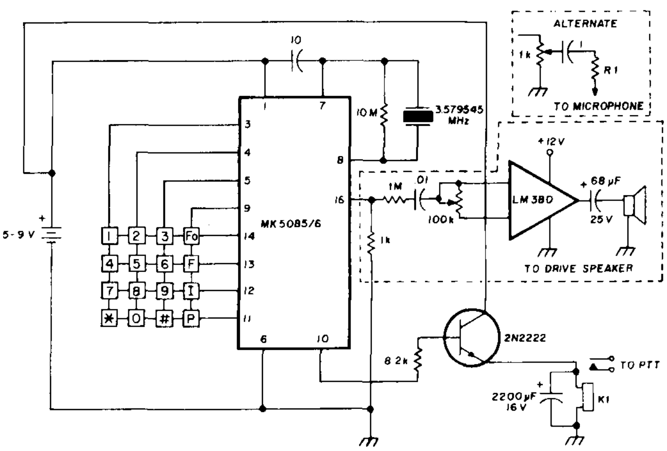

fig. 1. Schematic diagram of the complete Touch-Tone generator. The speaker can be eliminated and the output fed directly into the microphone input of a transmitter.

Depending upon the keyboard used, the correct IC can be selected from **fig. 3**. The MK5085/6-1 will operate with 3.5 to 10 volts applied while the MK5085/6-2 requires 4.5 to 10 volts dc. Current requirements are approximately 400 μA idling and 10 mA operating at 6 volts.

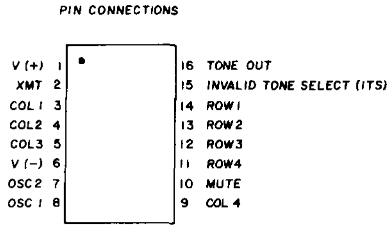

fig. 2. Pin-out of the MK5085/6. The ITS is grounded to eliminate any single tone outputs.

In my particular case, the internal portion of a 16 button pad was removed and a small printed circuit board substituted. This was not really necessary, but it provided more reliable tone generation than the original circuitry. To date, I believe this IC provides the average

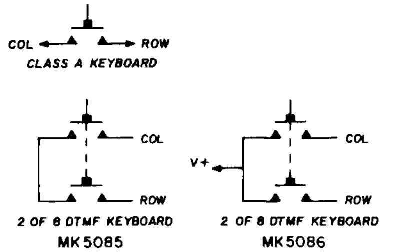

fig. 3. Keyboard connections to the MK5085/6.

ham the easiest way to generate correct tones for a minimum of expense.

reference

1. Mostek data sheet, *MK5085N/MK5086N Integrated Tone Dialer*, Mostek Corporation, 1215 West Crosby Road, Carrollton, Texas 75006.

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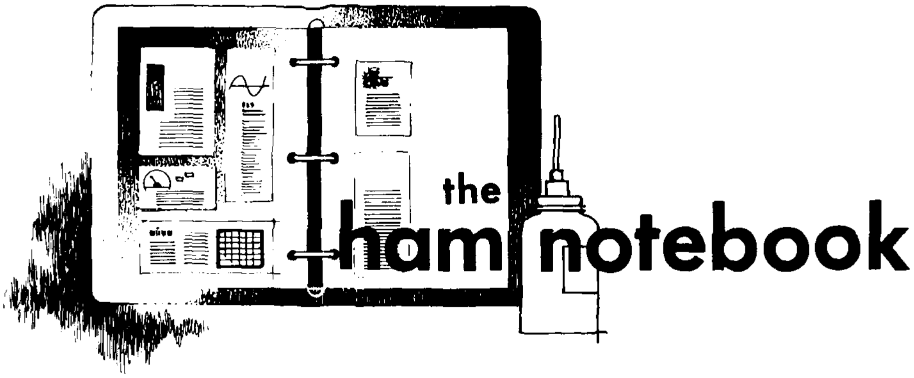
By Tim Ahrens, Post Office Box 895, Caswell AFS, Maine 04750



remote temperature sensor

Many times it is useful to know the temperature of an operational electronic device or component. An inexpensive temperature sensor which can be remotely installed inside a chassis or applied directly on a component to be checked, is a low cost silicon diode such as a 1N4004. The resistance of many diodes and other solid-state devices changes in a rather linear fashion vs temperature in the region from 32 to 212° Fahrenheit (0 - 100° C). A digital ohmmeter can be used to measure the "sensor" resistance (converted to temperature) after a simple calibration procedure has been completed and a chart similar to **fig. 1** is prepared. The actual measured resistances will vary from diode to diode, and from type to type, *but it is surprising how accurate these* simple sensors can be.

Calibration of a sensor is accomplished by applying crushed ice to a diode connected as shown in **fig. 1** to establish 32°F (0°C) temperature equivalent resistance. The 212°F (100°C) point can be established by placing the sensor in boiling water. It is best to allow 3 minutes or longer at both calibration points for the device to stabilize. Distilled water gives the most accurate results but I have used tap water as well. If you wish to compare intermediate points by using an industrial thermometer, be sure to *stir* the water to equalize the temperature because there is usually a measurable temperature gradient, from top to bottom, in a container of water being heated. Draw a straight line between the values charted on a linear graph paper.

The curve in **fig. 1** shows the small error (worst case 1.92%) of the sensor when compared to an expensive laboratory thermocouple meter.

Max J. Fuchs, WA1NJG

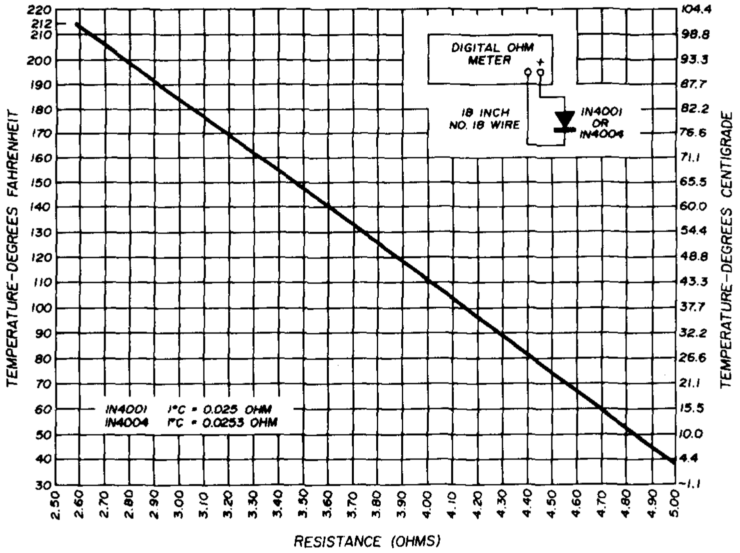


fig. 1. Temperature vs resistance curve for low-cost 1N4004 silicon diode. Values for 1N4001 diodes are nearly the same. Worst case deviation from linear slope is 1.92%.

75S-series crystal adapter

I recently acquired a Collins 75S-1 receiver. Navy MARS coverage was desired and I managed to locate a junk box 7081-kHz crystal that would temporarily allow me to cover the needed frequencies. It was a type HC-17/U which I was reluctant to alter to the HC-6/U package required by the receiver crystal board. There was also the problem of removing and replacing the crystals, their close spacing requiring needle-nosed pliers or similar device. I had no crystal/socket adapters on hand.

I solved the problem by removing the case and innards from a defunct HC-6/U crystal and soldering the tabs from a standard phenolic tube socket to the pins of the now empty HC-6/U crystal case. This construction alone has proven to be of sufficient strength although the assembly may be epoxied or incapsulated. With the adapter, HC-17/U crystals may be used (in fact, some FT-243s I tried also worked well), and are easily removed and/or exchanged.

Paul K. Pagel, K1KXA

Collins 70E12 pto repair

After twenty-five years of faithful service my Collins 75A2 receiver quit. An extensive search uncovered the unhappy fact that its permeability-tuned vfo or pto had a shorted tubular, ceramic coupling capacitor.

Since factory service was out of the question in terms of time and money, I decided to remove the pto myself and try to repair it. Here's what I did.

I used a short Philips screwdriver to remove the three screws holding the unit to its mounting plate in the receiver. In fact, I *made* a screwdriver to do this because I didn't happen to have one of the right size. You'll be luckier. I then snipped three wires and unsoldered the coax that goes to the 6BA7 second mixer tube. After I removed the pto cover, it was easy to replace the shorted capacitor with two 0.0047 μF silver mica capacitors.

I next replaced the pto unit — without its cover — in the receiver because I wanted to adjust its frequency calibration. Surprise! It was 8 kHz off when I re-installed it, but I was able to adjust it to within about 1 kHz. So far, so good, but now I had to remove the unit again to put its cover back on, and then re-install it a second time. Drat! Calibration was now 35 kHz off over the 1 MHz range. I removed it for the third time, and by now had become an expert in removing and replacing ptos.

Then I got a bright idea: Why not drill a small access hole in the pto can opposite the trimmer inductor, and also file a small screwdriver access notch in the pto mounting plate? I also oiled the lubricating washer with *Three-in-One* oil, and applied a dab of cold cream to the screw. I figured that if it's good for the face it shouldn't hurt the pto.

This time, after everything was back together, I made a small aluminum-wire tuning tool to reach the trimmer inductor through the hole I made in the pto can. Final calibration was less than 1 kHz from one end of the dial to the other. My 75A2 is now perking again better than ever, and I saved myself a whole lot of money in the bargain.

Oscar Tripancy, W6BIH

safety circuit for pushbutton switches

A number of neat pushbutton switches has appeared on the surplus market, and these switches are being used for a variety of purposes around the ham shack. One common type is a bank of dpdt or 4pdt buttons ganged mechanically so that pushing one releases the others. This switch might be used, for example, to select one of a bank of crystals or to power up one of a group of circuits. Usual wiring ignores the normally-closed contact and applies the power (or ground) to all the commons in parallel. While the mechanical linkage releases the other buttons when one is pressed, it does not prevent simultaneously pressing (and locking) two buttons, thereby activating two separate circuits.

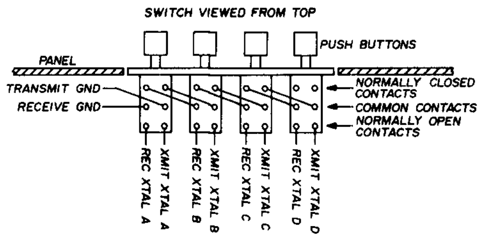


fig. 1. Method of wiring multiple pushbutton switches so that two circuits cannot be connected at the same time, even though two buttons are pushed simultaneously.

If activating two circuits is undesirable (as with a crystal selector), this possibility can be prevented by wiring the common of each pushbutton through the normally-closed contact of the previous switch so that the power (or ground) is carried as far as the first button depressed but not beyond (see **fig. 1**).

Richard Fleck, K3RFF
David McLanahan, WA1FHB

ICOM-22A wiring change

Recently, while operating my IC-22A from the home station on 146.52 MHz simplex, I noticed the receiver had a slow recovery. Also, the in-line bridge indicated the emission of power at a low level. I further noted a low growling noise from the speaker at this time when I held my ear close to the speaker. Upon investigation of the circuit diagram and the wiring of the transceiver, I found what was an apparent wiring error.

PL1 and PL2 (the dial and S-meter lamps) are connected to the input side of the whine filter choke L35. It was also noted that another lead was connected to the same point on the terminal strip, from R3, the 100-ohm series resistor connected to PL3, the transmit indicator lamp. According to the wiring diagram, this lead should be connected to the *output* side of the whine filter (the junction of L35, C94, R102, and the common of S102).

After disconnecting the lead from the terminal strip and soldering it to the common of S102 (that side of the *high-off-low* switch which has an empty terminal) the problems disappeared. In addition, the small amount of alternator whine which was audible in the external speaker while mobile is now nonexistent. **Caution**: Do not connect the wire from R3 to the empty terminal of S102, but to the *common of the switch* which is the *center terminal* on that side of the switch.

Paul K. Pagel, K1KXA

low-cost copper antenna wire

I've found that copper antenna wire is either unavailable in the quantities that I need or is priced so high that I can't afford it; sometimes both.

Quite by accident an acceptable solution to the problem presented itself while I was in a local sporting-goods store looking for another item. A fisherman, who does a lot of lake-trout trawling, was buying stranded copper trawling wire in 300-foot (100m) lengths at what seemed to be a ridiculously low price. After he left, I questioned the proprietor about the availability of the line, and he answered, "No problem, I can get all I want."

Since then, I've become an avid antenna builder and use this material for all my wire antennas. The wire is a seven-strand, twisted copper wire that solders easily and has a diameter approximately equivalent to no. 16 AWG (1.3mm) wire. The only shortcoming I've found is that the wire will stretch under load over a period of time, sometimes as short as a month or so. Consequently I use it for inverted vees and other antennas where the wire doesn't have to bear all the load or strain of the connectors and coaxial cable. I've discovered, however, that I can easily trim or "prune" the wire to its orignal length after it has stretched for awhile. Stretching also appears to "cold-work" the wire slightly and is less pronounced after the initial deformation. Price? Well, the last 600-foot (200m) spool I bought cost only a bit over one cent per foot!

Jim Gray, W2EUQ

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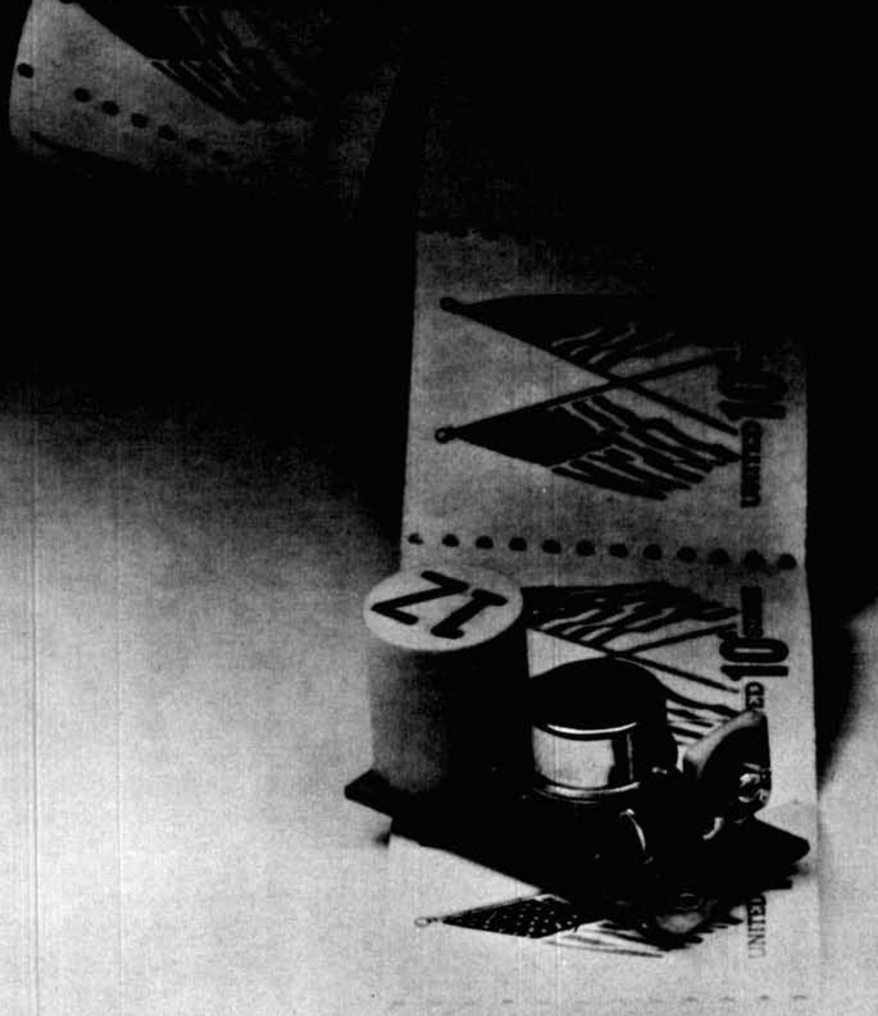

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comments

memory keyer

Dear HR:

Since the popular WB9FHC memory keyer article was published[1] several modifications have been introduced for this relatively simple, low-cost circuit.[2,3,4] A significant disadvantage of the original circuit is the asynchronous clock, which allows sporadic keying anomalies. At low speeds a dot or dash may be lost if the paddle is hit and released between clock pulses. In addition, a "lost" dash may show up the next time the *dot* paddle is pressed. This phenomenon is the result of the master-slave flip-flop having an inherent memory at its J and K inputs. When the clock pulse is *high*, a brief *high* at the J input will be saved and clocked out when the clock goes low. While the clock is *low*, the J input will not accept a *high*. K3NEZ eliminated the unwanted dash by connecting the clock input of the dash flip-flop to the Q output of the dot flip-flop.[2] Thus, the dash flip-flop data inputs are disabled between characters by a low at the clock input.

At W6OCP, a different solution was found. Both disadvantages of the circuit were minimized by changing the duty cycle of the NE555V from a square wave to a series of short low-going pulses. Thus, the inputs to both the dot and dash flip-flops are enabled between clock pulses, and no characters are lost.

1. Michael Gordon, WB9FHC, "Electronic Keyer with Random-Access Memory," *ham radio,* October, 1973, page 6.
2. Howard M. Berlin, K3NEZ, "Memory Keyer" (Comments), *ham radio*, December, 1974, page 58.
3. Howard M. Berlin, K3NEZ, "Increased Flexibility for the Memory Keyer," *ham radio,* March, 1975, page 62.
4. Howard M. Berlin, K3NEZ, "RAM Keyer Update," *ham radio,* January, 1976, page 60.

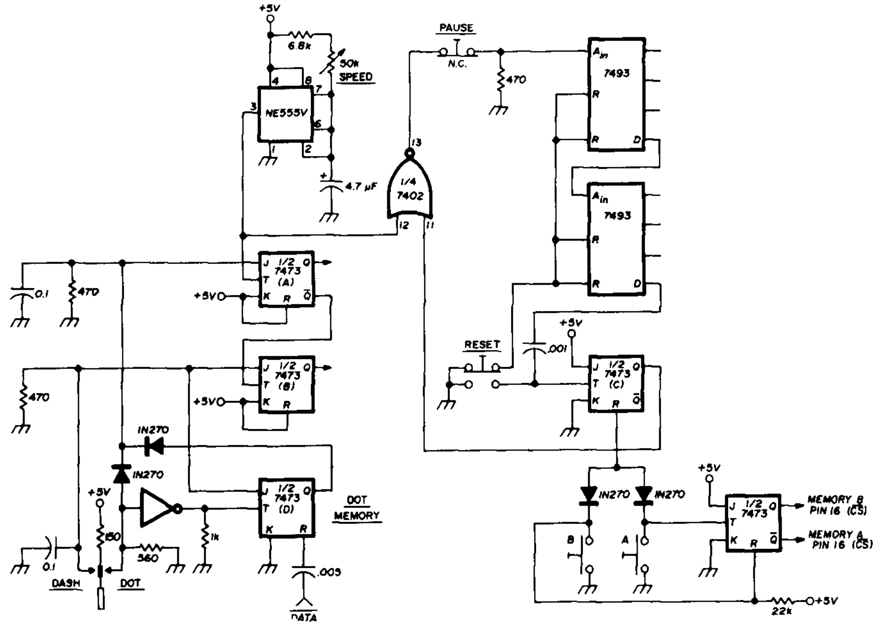


fig. 1. Modifications to WB9FHC's memory keyer eliminate sporadic keying anomalies. Also added are a dot memory, pause and reset, and pushbutton select and start.

A dot or dash is "remembered" and will be heard when the next clock pulse arrives. **Fig. 1** shows the modified NE555 diagram.

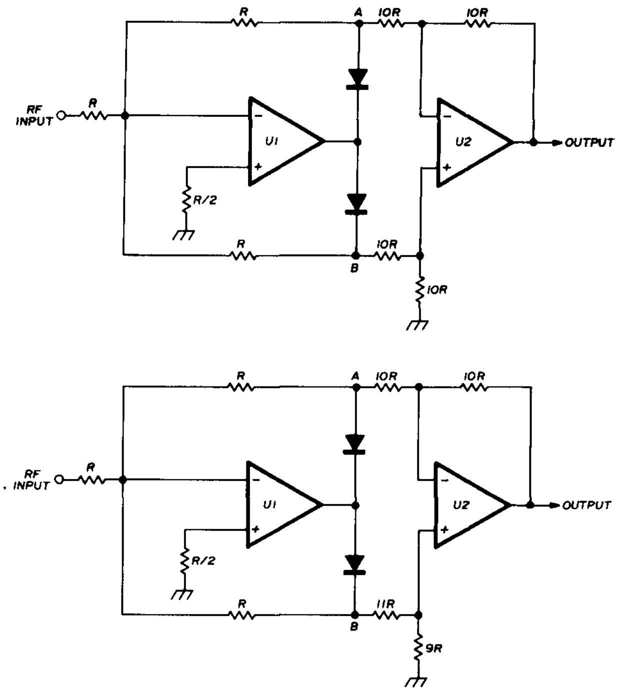
It should be noted that this memory is not equivalent to a dot memory which prevents dots from being lost when the dot paddle is hit during a dash, as in the letter N. This feature is essential for all but the most coordinated CW operator. The dot memory shown in **fig. 1** was adapted from January, 1975, *QST*[5] and makes use of the master-slave input memory. The unused half of the start/stop flip-flop, a 7473, can be connected as shown for this purpose.

The 100 mA transformer supplied with the kit is barely adequate to supply the board's current needs, thus limiting the number of extra logic functions which can be added. The circuit changes shown reflect this problem; if a heftier 5-volt supply is used, diodes and double-throw pushbuttons can be replaced with cleaner circuitry using gates and inverters.

I have found pushbutton select-and-start to be important for contest efficiency, but needed a way to cancel a message in case of error. The circuit shown accomplishes this without additional chips. The use of an inverter could eliminate the reset-followed-by-stop action of the spdt pushbutton.

A pause feature can be added using another such switch, also shown in **fig. 1.** Once the timing skill is developed, this control can be used to insert repeats or additional words in a transmitted message. A more complex circuit would

5. James H. Fox, WA9BLK, "An Integrated Keyer/TR Switch," *QST,* January, 1975, page 15.



Schematic diagram of the improved full-wave detector with new resistor values.

gate the memory output, eliminating the possibility of stopping the message with the transmitter keyed.

Jerry Holter, W6OCP
Menlo Park, California 94025

diode detectors

Dear HR:

I enjoyed Hank Olson's article on "Diode Detectors" in the January, 1976, issue of *ham radio*, but would like to point out an error in his "improved" rectifier circuit of **fig. 11** (shown below). The circuit as shown is not balanced, and a page or two of algebra shows that the correct ratio for the second stage lower input divider is *9R* - *11R* and not *10R* - *10R* as shown. In addition, the circuit is not new. If you let the upper divider values be *R* and *R* (instead of *10R*), the lower divider ratio goes to unity (i.e., it drops out) and the circuit is identical to one I published in *Electronic Design* in 1967.*

Allan Lloyd, W2ESH
Hawthorne, New Jersey

Strictly speaking, Mr. Lloyd's criticism of the improved rectifier circuit is valid. The slight error occurs because point **A** *drives a resistance of 10R (since the inverting input of U2 is a virtual ground) and point* **B** *drives a resistance of 20R (the input impedance of U2's non-inverting input is very high). That is, points* **A** *and* **B** *are driving different impedances by a 2:1 ratio. Since these impedances were deliberately picked to be considerably larger than the impedances driving them, little imbalance occurs (comparable with the resistor tolerances typically used in amateur projects).*

If one wants to be absolutely accurate, Mr. Lloyd's advice should be heeded, and the circuit values changed as in the schematic above. Of course, **fig. 13** *in the original article has a small potentiometer to correct for this problem and that of resistor tolerances.*

Until Mr. Lloyd's letter arrived I was not aware of his "Ideal Rectifier" circuit which was published previously in Electronic Design. To my knowledge, the circuit was the design of Dr. Nicholas Cianos, to whom I gave credit in the article.

Henry D. Olson, W6GXN

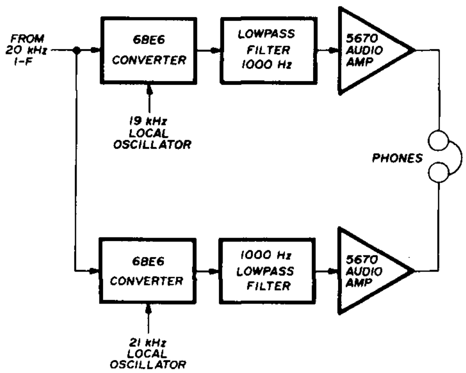
*Allan Lloyd, "Ideal Rectifier Uses Equal-Value Resistors," (Ideas for Design), *Electronic Design*, June 21, 1967, page 96. For further comments and additional features of this interesting but tricky circuit, see "letters" column of *Electronic Design*, October 11, 1967, page 46; and December 20, 1967, page 48.

binaural cw reception

Dear HR:

The article, "Synthesizer for Binaural CW Reception" in the November, 1975, issue of *ham radio* was particularly interesting because, back in the early 1950s as W1OPN, I built an outboard unit for my homebrew receiver to achieve a similar effect to the one author Hildreth describes. In my case the center frequency from the narrow band i-f produced equal 1000 Hz notes in each ear. Tuning through the signal, from left to right for example, resulted in a low frequency beat note (left ear) rising to 1000 Hz (both ears) and then dropping in frequency again (right ear). As I recall, the left-to-right effect was not too impressive, but I'm sure Hildreth's state-of-the-art approach makes it most worthwhile. A block diagram of the system I used is shown below.

The really dramatic results, and the reason I write, occured when I tuned one of the well-isolated local oscillators to almost the same frequency as the other oscillator. The very small frequency difference (or was it phase) provided the strong sensation that the desired signal stood out in three-



dimensional space. The result was a true stereo sensation with "depth and presence" as the ads say, a sensation that made CW copy unique.

As I usually do, I tore the unit down and went on to something else. If I ever finish modifying my current solid-state receiver, I want to try this experiment again. Perhaps some other *ham radio* readers would like to try it too.

David L. Anthony, W5NOE
Columbus, Texas

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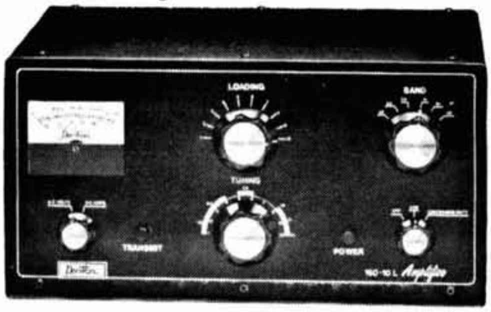

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NEW products

flexible antennas for two-meter hand-helds

Antenna Specialists recently announced a new line of "Rubber Ducky" type antennas for two-meter hand-held transceivers. These antennas are designed for units using type-F TNC, or BNC antenna connectors, and all are protected by high quality, molded plastic sheaths. The HM-226 (TNC-type) is designed for the newer *Wilson* brand transceivers, and is priced at $11.50; the HM-227 (BNC-type) is designed for many brands, including *Genave*, and is priced at $9.50; and the HM-228 (F) is designed for the older *Wilson*, *Tempo*, and other brands, and is priced at $8.75. For additional information write the Antenna Specialists Company, 12435 Euclid Avenue, Cleveland, Ohio 44106.

500 MHz frequency counter

Davis Electronics recently announced its new CTR-2 Frequency Counter with prescaler that covers 500 MHz with an accuracy of 0.00002 per cent. Features of the new counter include a full 8-digit display, large 0.3 inch (7.6mm) LED readouts, automatic decimal point placement, 1-Hz resolution, high input sensitivity, and automatic input limiting. The CTR-2 has selectable gate times of 1 millisecond and 1 second, with provision for 10 seconds, and a high-stability 10 MHz TCXO time base. This counter is recommended for any frequency measuring task from 1 Hz to 500 MHz – audio through ultra-high frequencies – and is guaranteed for one year. Delivery from stock at only $349.95. For more information and *free* literature, write Davis Electronics, Dept. JJ, 636 Sheridan Avenue, Tonawanda, New York 14150.

floppy disk

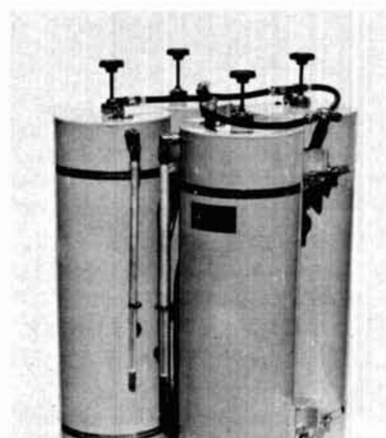
Imsai, San Leandro, California, recently announced the availability of a floppy disk drive with an intelligent interface/controller. The system is specifically designed for use with the Imsai 8080 computer, and offers the user a number of benefits heretofore not provided by other manufacturers.

The floppy disk has a capacity of 243k bytes using the IBM 3740 format. The interface/controller contains its own processor and direct access memory which operate independently but under command of the main processor of the Imsai 8080, enabling the main processor to perform other tasks while a disk operation is in process. Also, the user can change the program format of the disk by reprogramming the interface EPROM (erasable programmable read only memory) chips. Up to four floppy disk drives can be controlled by one interface/controller. Each disk can be write-protected by software control.

The disk drive comes in a cabinet with a power supply and the capacity to accommodate a second drive. A rack-mounted version is also available. All interconnection cables are included. The Imsai Floppy Disk Drive and Interface/Controller are $1,649 assembled and $1,449 unassembled. An additional disk drive without cabinet is $925. The Interface/Controller alone is $799 assembled and $599 unassembled. Disk Operating System software is available on diskette for $40. Also, 12k Extended BASIC with disk access capability is available.

For additional information, write IMS Associates, Incorporated, 14860 Wicks Boulevard, San Leandro, California 94577; telephone (415) 483-2093.

bpbr circuit duplexers



Wacom Products, Inc., of Waco, Texas has announced a new line of duplexers which include the use of a new exclusive circuit developed by the company. When used with a high-*Q* filter, the *BpBr Circuit* provides superior suppression of spurious and

More Details? CHECK–OFF Page 118

sideband noise between the adjacent duplex frequencies, particularly when the duplex frequencies are close-spaced. A patent is pending on the new circuit. new circuit.

Model WP-641 consists of four 8-inch (20cm) OD cavities with the BpBr Circuit, and is designed for use with duplex stations in the 144-174-MHz band when the transmit-to-receive frequency separation is 500 kHz or more. It provides bandpass characteristics near the pass frequencies and band-reject cavity characteristics at the frequencies to be attenuated. Superior transmit-to-receive isolation is a feature of the new model.

For additional information contact Wacom Products, Inc., Box 7307, Waco, Texas 76710; or telephone (817) 776-4444.

gutter-mount mobile antennas

Hamline Electronics recently introduced a new line of easily-installed vhf mobile antennas featuring a stressed-aluminum gutter-mount bracket and quarter-wave elements for 146-MHz and 220-MHz applications. The bracket includes an SO-239-type connector with ten feet of RG58/U coaxial cable. A simple, plastic-tipped stabilizing screw permits the bracket to be adjusted for any vehicle rain gutter so that the antenna will be vertical. Two mounting screws threaded into a clamping plate secure the assembly in minutes to a particular automobile.

The antenna elements are made from resilient steel and are vinyl-clad for protection from weather. Each element is mounted in a non-tarnishing PL-259-type plug and sealed with epoxy to form an electrically sound, weatherproof, quickly-detachable assembly.

The FME-146 element for 2 meters, and the FME-220 element for 1¼ meters may be purchased separately for only $4.95 each, postpaid. The mounting bracket with one element is priced at only $15.95 postpaid. Please specify the element desired when ordering. (Pennsylvania residents please include 6% sales tax.)

For additional information, write Hamline Electronics, Box 52, Sweet Valley, Pennsylvania 18656; telephone (215) 929-8118 (preferred) to (717) 256-3017.

active filter useful to 10 kHz

A new series of IC active filters designed for use at frequencies up to 10 kHz has been developed by National Semiconductor Corporation. Called the *AF100 series*, the new integrated circuits are intended for use in low frequency analog systems, including medical, geophysical, sonar, audio, tone signaling, modem, and feedback control systems where specific filter functions are required.

The AF100 series filters are basic building blocks that can be used to construct any filter response such as Butterworth, Bessel, Cauer, and Tschebycheff. With the addition of *only four external resistors, the AF100* can be programmed for second order functions.

Lowpass, highpass, and bandpass functions are available simultaneously at separate outputs, and notch and all-pass functions are available by combining these outputs in an internal summing amplifier. If higher order systems are required, several AF100s can be cascaded. In all configurations, the *Q*, gain and center frequency adjustments are independent, requiring no iterative trimming. Other features of the new active filter series include a *Q* range of up to 500 and a frequency accuracy of either ±1% or ±2.5%. Operating power supply range is from ±5 volts to ±18 volts and supply current is 4.5 mA maximum.

The new Active Filter series is available in either a 16-pin plastic dual in-line package or a 12 pin TO-8 can for operation over the commercial temperature range of from −25°C to +85°C, and in the TO-8 can for operation over the military temperature range of from −55°C to +125°C. In quantities of 100, the commercial plastic CIP active filters with a frequency tolerance of ±2.5% (the AF100-1CJ) sells for $4.95 each.

For more information write

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National Semiconductor, 2900 Semiconductor Drive, Santa Clara, California 95051; or telephone (408) 737-5000.

shure mikes

Shure Brothers offers two new dynamic element communications microphones that set new standards for ruggedness, reliability, and transmission quality in safety, tranportation, and industrial communications applications.

The Model 524C *Ranger 2* is a transistorized unit designed to match carbon microphone-type circuits and significantly improve intelligibility and performance. Its built-in transistorized amplifier supplies sufficient output to permit the use of up to 30m (100 ft) of unshielded cable, while offering a wide frequency response.

The Model 577 *Sonobar* combines a noise-cancelling pickup pattern and a "tailored" voice-range frequency response to block out unwanted noise and boost close-up voice signals, ideal for all fixed-station and mobile applications where high ambient noise conditions are a problem.

The new Shure Model 577 Sonobar microphone is available in high or low impedance models, and a transistorized model for carbon microphone-type circuits. The new 577 series replaces the now-discontinued Shure 488 series, with the exception of the FAA-approved 488T which is still available.

User net prices of these new microphones are: Model 524C *Ranger 2*, $66; the 577A (high impedance), $76.75; the 577B (low impedance), $76.75; and the transistorized 577C replacement for carbon microphones, $84.75.

For additional information write Shure Brothers, Inc., 222 Hartrey Avenue, Evanston, Illinois 6C204.

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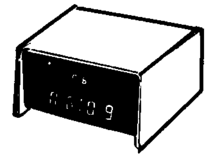
Printed Circuit Board for kit # 850-4 (etched & drilled fiberglass) $2.95
Mini-Brite Red LED's (for colon in clock display) pkg. of 5 .... 1.00
Molded Plug Transformer 115/10 VAC (with cord) 2.50
NOTE: Entire Clock may be assembled on one PC Board or Board may be cut to remote display.
Kit # 850-4 will fit Plexiglas Cabinet II.



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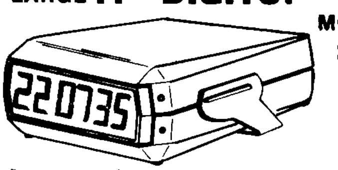
3"x6"x1/8" **95¢ ea. 4/$3**

MOBILE LED CLOCK

12 OR 24-HOUR OPERATION
12 VOLT AC or DC POWERED FOR FIXED OR MOBILE OPERATION.
SIX LARGE .4" DIGITS!

KIT OR ASSEMBLED — **MODEL 2001**



ACCURATE TIME WITH ADJUSTABLE XTAL TIME BASE

Approx. Size: 1¾"H x 4"W x 4½"D

BATTERY BACK-UP FOR POWER FAILURE OR TRANSPORTING FROM HOUSE TO CAR, ETC.

- 6 JUMBO .4" RED LED'S BEHIND RED FILTER LENS WITH CHROME RIM.
- SET TIME FROM FRONT VIA HIDDEN SWITCHES • 12/24-Hr. TIME FORMAT
- STYLISH CHARCOAL GRAY CASE OF MOLDED HIGH TEMP. PLASTIC
- BRIDGE POWER INPUT CIRCUITRY — TWO WIRE NO POLARITY HOOK-UP
- OPTIONAL CONNECTION TO BLANK DISPLAY (Use When Key Off in Car, Etc.)
- TOP QUALITY PC BOARDS & COMPONENTS - EXCELLENT INSTRUCTIONS
- MOUNTING BRACKET INCLUDED

KIT #2001 COMPLETE KIT (Less 9V. Battery) **29.95 EA.** 3 OR MORE **$27.95 EA.** 115 VAC Power Pack #AC-1 **$2.50 EA.**

ASSEMBLED UNITS ORDER #2001 WT WIRED & TESTED (LESS 9V. BATTERY) **$39.95 EA.** 3 OR MORE **$37.95 EA.** Assembled Units May Be Mixed With Kits for Qty. Price
WIRED FOR 12 HR. OP. IF NOT SPECIFIED OTHERWISE

JUMBO RED LED's 12/$1.00 50/$3.95

6 Digit-LED Clock-Calendar-Alarm Kit

This is a complete, top of the line, Kit for the person that wants the best. Some of the many features and options are: 12/24 time, 28-30-31 day calendar, alternates time (8 sec) and date (2 sec) or can display time only and date on demand, 24 hr alarm - 10 minute snooze, alarm set indicator, 50/60 HZ. line operation or use with Xtal time base (#TB-1), built in OSC for battery back-up / AC failure, Aux. timer, CHOICE OF DIGITS.

Kit #7001B	**6 - .4" Digits**	**$39.95**
Kit #7001C	**4 - .6" Digits & 2-." [Seconds]**	**$42.95**
Kit #7001X	**6 - .6" Digits**	**$45.95**

Kits are complete (less cabinet) including PC boards, power supply, IC socket, 9 switches, 16 transistors and all parts required for above features and options **[All #7001 Kits Will Fit Cabinet I Above]**

60 HZ. XTAL TIME BASE KIT

Will enable Digital Clock or Clock-Cal. Kits to operate from 12VDC. Uses MM5369 and 3.58MHZ. XTAL. Req. 5-15VDC/2.5 MA. 1"x2" PC Board. Easy 3 wire hookup Accuracy: +- 2 PPM

#TB-1 [adjustable]
Complete kit $4.95 ea
Wired & Cal. $9.95 ea

PRINTED CIRCUIT BOARDS for CT-7001 Kits sold separately with assembly info. PC Boards are drilled Fiberglass, solder plated and screened with component layout. Specify for # 7001B or # 7001C (Set of 2) $7.95

JUMBO DIGIT CLOCK KIT

A complete Kit (less Cabinet) featuring: six .5" digits, MM5314 IC, 12/24 Hr. time, 50/60 HZ., Plug-Transformer, Line Cord, Switches, and all Parts.
[Ideal Fit in Cabinet II]
Kit #5314-5 .... **$19.95 ea. 2/$38.**

JUMBO DIGIT CONVERSION KIT

Convert small digit LED clock to large .5" displays. Kit includes 6-.5" LED's, Multiplex PC Board & easy hook-up info.

Kit #JD-1CC For common Cathode
Kit #JD-1CA For common Anode **$9.95 ea. 2/$19.**

SCHOTTKY TTL

74S00	$ .35
74S01	.40
74S04	.55
74S05	.60
74S09	.55
74S10	.40
74S15	.55
74S20	.50
74S22	.45
74S40	.45
74S50	.45
74S51	.55
74S60	.85
74S64	.55
74S73	1.25
74S74	.85
74S75	1.75
74S78	1.50
74S86	.95
74S107	.95
74S112	.95
74S113	1.40
74S114	.95
74S121	.95
74S133	.75
74S134	.75
74S138	1.75
74S139	1.50
74S151	1.95
74S153	1.95
74S155	1.95
74S156	1.95
74S157	1.80
74S158	2.50
74S174	2.50
74S175	2.50
74S181	2.95
74S182	1.95
74S251	2.75

DTL

930	$.09
932	.09
937	.09

LED DRIVERS

7447	$ .95
7448	.95
75491	.65
75492	.65

VOLTAGE REGULATORS

LM 309 H	TO-5	$ .95
LM 309 K	TO-3	1.25
7805	TAB	.95
7812	TAB	1.25
7815	TO-3	1.25
7815	TAB	1.25
78L 15	TO-5	.75
7824	TO-3	1.25
723	DIP	.75
723	TO-5	.75

DIGITAL CLOCK IC's

MM 5312	$ 4.95
MM 5314	3.95
MM 5375 AB	3.95
CT-7001	7.95
CT-7002	13.95
50380	3.95
MM 5369	2.50

XTAL

3.579545 MHZ. $ 1.95

PRESCALE

11C90DC	$15.95
95H90	9.95

DIODES

IN 4002	1A, 100 PIV	12/$1.00
IN 4005	1A, 600 PIV	11/$1.00
IN 4007	1A, 1000 PIV	10/$1.00
RECTIFIER	2.5A, 1000 PIV	4/$1.00
IN 914	SIL. SIGNAL	20/$1.00
IN 4148	SIL. SIGNAL	20/$1.00
DYAC	28V.	4/$1.00

PLUG TRANSFORMERS

12 VAC at 150 MA	$ 2.50
12 VAC at 500 MA	3.50

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555	TIMER	2/$1.00
556	DUAL TIMER	.95
565	PLL	.95
566	FUNCTION GEN.	1.75
567	TONE DECODER	1.75

IC SOCKETS

PINS	1-24	25	100
8	$ .25	$ .22	$ .20
14	.25	.22	.20
16	.28	.25	.23
18	.31	.28	.26
24	.50	.45	.40
28	.60	.55	.50
40	.75	.70	.65

MEMORY

21L02 IK RAM $1.95

EXAR

XR 2556	$ 1.75
XR 2567	$ 1.95

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2N2222A	TO-18	5/$1.00
2N3415	TO-92	5/$1.00
2N3704	TO-92	5/$1.00
2N4249	TO-92	5/$1.00
2N4400	TO-92	5/$1.00
2N4437	TO-92	5/$1.00
2N5089	TO-92	5/$1.00
2N5457 N	J-FET	.95

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MINI-SLIDE SPDT	5/$1.
REG. SLIDE DPDT	6/$1.
PUSH BUTTON N.O.	3/$1.
MINI TOGGLE SPDT	$1.30
MINI TOGGLE DPDT	1.50

TRANSISTOR SOCKET TO-5/18 GOLD PINS
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8" TIE-WRAP	100/$1.95
4" TIE-WRAP	100/$1.75

MOLEX PINS

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STRIP OF 100	1.25

MISC. PRIME IC's

FAIRCHILD 9316 (74161)	$ .95
75234 DUAL CORE SENSE AMP	1.50
MM 502H TO-5 SHIFT REG	.95

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301	TO-5
709	DIP
709	TO 5
741	DIP
741	M-DIP
741	TO-5
747	DIP
748	DIP

DISCRETE LED's
JUMBO RED
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50/$3.95
100/$7.50

PC TRIM POTS

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4.7K	6/$1.00

SPECTROL 10K 10 TURN
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BUY 100 OR MORE IC's [*Any Mix*] TAKE 10% DISCOUNT.

Fairchild Super Digit FND-359

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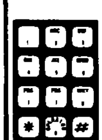

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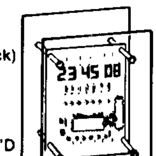
5/32" thick
$4.95
6/$28.

SEE THE WORKS Clock Kit
Clear Plexiglas Stand

- 6 Big .4" digits
- 12 or 24 hr. time
- 3 set switches (back)
- Plug transformer
- all parts included

Plexiglas is Pre-cut & drilled
Size: 6"H, 4⅓"W, 3"D



A SUPER LOOKING CLOCK!

Kit #850-4 CP **$23.50 ea. 2/$45.**

7-SEG LED

COMMON CATHODE

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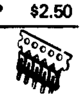
FND-503	RED	.5"	RHDP	$1.35
DL-750	RED	.6"	LHDP	$2.95
XAN-654	GREEN	.6"	NDP	$2.95
XAN-664	RED	.6"	NDP	$2.95

COMMON ANODE

DL-747	RED	.6"	LHDP	$2.95
XAN-72	RED	.3"	LHDP	$1.25
XAN-81	YELLOW	.3"	RHDP	$1.75
XAN-351	GREEN	.3"	RHDP	$1.50
XAN-361	RED	.3"	RHDP	$1.50
XAN-362	RED	.3"	LHDP	$1.50
XAN-662	RED	.6"	NDP	$2.50
XAN-692	RED	.6"	NDP	$2.50

Form Inexpensive Sockets 100 for $1.25 Reel of 1000 - $8.50 — **MOLEX PINS**



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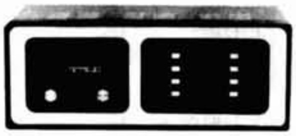

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CLOCKS

6 digit AUTOMOTIVE CLOCK KIT complete with a CRYSTAL TIMEBASE accurate to .01 percent. 12 volts d.c. operation – built in noise suppression and voltage spike protection. Readouts blank when ignition is off – draws 25 mA in standby mode. Has .3 in. readouts. Use it in your car or for all applications where a battery-operated clock is needed. Approximate size 3" x 3.5" x 1.75"

WITH BLACK PLASTIC CASE	$34.95 ppd.
WITHOUT CASE	$29.95 ppd.
ASSEMBLED AND TESTED	$45.95 ppd.

CMOS CRYSTAL TIMEBASE KITS with .01 percent accuracy. 5-15 v.d.c. operation. Draws only 3 mA at 12 volts. Single I.C. – very small size – the P.C. board is 7/8" x 1-5/8". Choose a main output of 50 or 100 Hz., 60 Hz., 500 or 1000 Hz., or 1 Hz. Several related frequencies are also available on each board, in addition to the main ones listed above. Be sure to specify the Frequency you want. All kits are $10.95 ppd.

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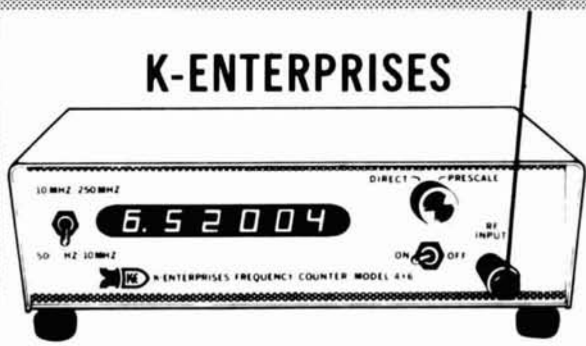

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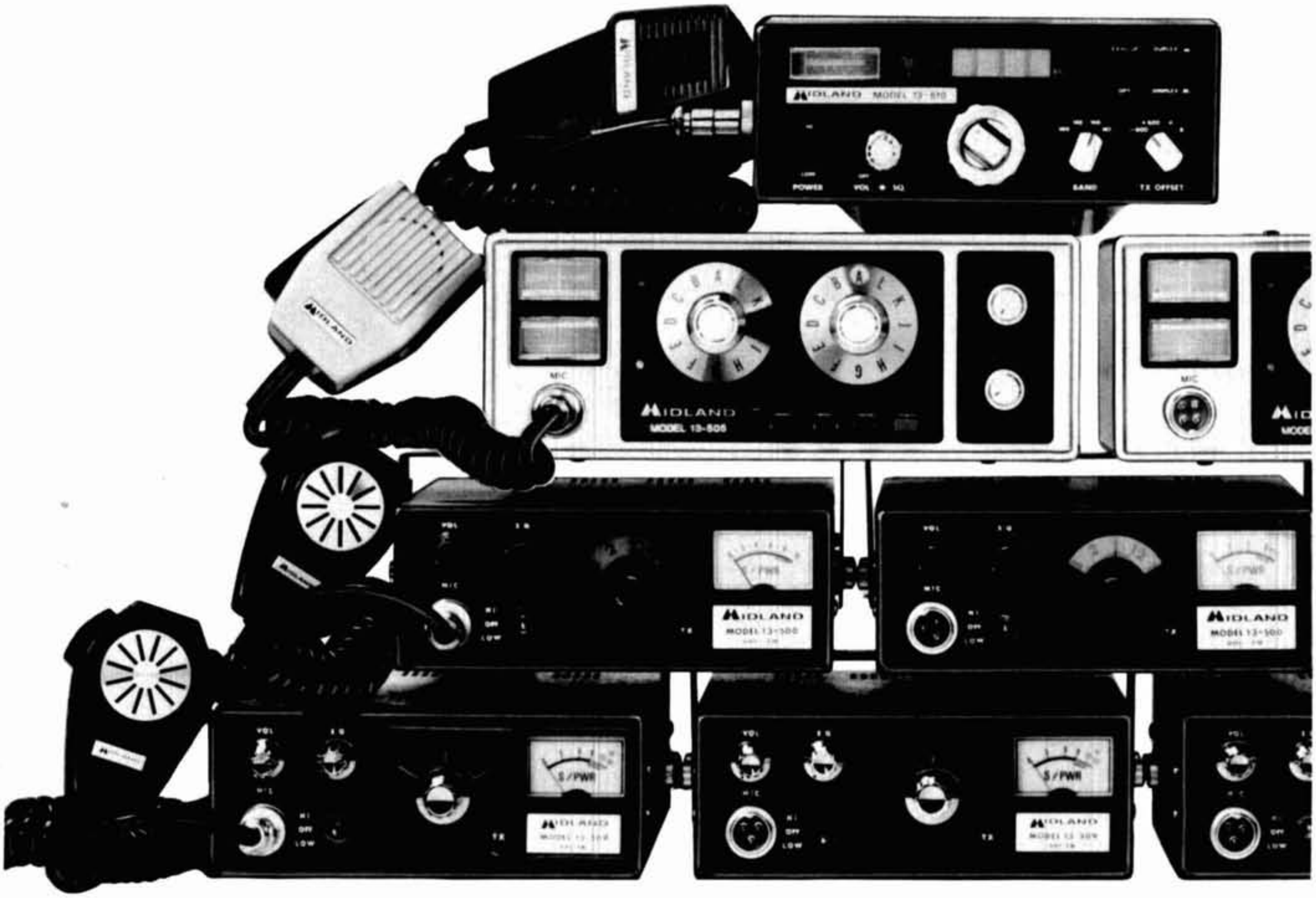

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More Details? CHECK–OFF Page 118

7400N TTL

SN7400N	16	SN7459A	25		
SN7401N	16	SN7460N	22	SN74154N	1.00
SN7402N	21	SN7470N	45	SN74155N	99
SN7403N	16	SN7472N	39	SN74156N	99
SN7404N	18	SN7473N	37	SN74157N	99
SN7405N	24	SN7474N	32	SN74160N	1.25
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SN7408N	25	SN7479N	5.00	SN74164N	1.10
SN7409N	25	SN7480N	50	SN74165N	1.10
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SN7412N	33	SN7485N	89	SN74170N	2.10
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SN7420N	21	SN7491N	75	SN74176N	90
SN7421N	33	SN7492N	49	SN74177N	90
SN7422N	49	SN7493N	49	SN74180N	99
SN7423N	37	SN7494N	79	SN74181N	2.49
SN7425N	29	SN7495N	79	SN74182N	95
SN7426N	29	SN7496N	89	SN74184N	1.95
SN7427N	37	SN7497N	4.00	SN74185N	2.20
SN7429N	42	SN74100N	1.00	SN74186N	15.00
SN7430N	26	SN74107N	39	SN74187N	6.00
SN7432N	31	SN74121N	39	SN74188N	3.95
SN7437N	27	SN74122N	39	SN74190N	1.19
SN7438N	27	SN74123N	50	SN74191N	1.25
SN7439N	25	SN74125N	60	SN74192N	89
SN7440N	15	SN74126N	60	SN74193N	89
SN7441N	89	SN74132N	1.09	SN74194N	1.25
SN7442N	59	SN74136N	95	SN74195N	75
SN7443N	75	SN74141N	1.15	SN74196N	1.25
SN7444N	75	SN74142N	4.00	SN74197N	75
SN7445N	75	SN74143N	4.50	SN74198N	1.75
SN7446N	81	SN74144N	4.50	SN74199N	1.75
SN7447N	69	SN74145N	1.15	SN74200N	5.59
SN7448N	79	SN74147N	2.35	SN74279N	90
SN7450N	26	SN74148N	2.00	SN74251N	1.79
SN7451N	27	SN74150N	1.00	SN74284N	6.00
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CD4007	25	CD4042	1.90	74C42N	2.15
CD4009	59	CD4044	1.50	74C73N	1.50
CD4010	59	CD4046	2.51	74C74	1.15
CD4011	25	CD4047	2.75	74C90N	3.00
CD4012	25	CD4049	79	74C95N	2.00
CD4013	47	CD4050	79	74C107N	1.25
CD4016	56	CD4051	2.95	74C151	2.90
CD4017	1.35	CD4053	2.95	74C154	4.00
CD4019	55	CD4060	3.25	74C157	2.15
CD4020	1.49	CD4066	1.75	74C160	3.25
CD4022	1.25	CD4069	45	74C161	3.25
CD4023	25	CD4071	45	74C163	3.00
CD4024	1.50	CD4081	45	74C164	3.25
CD4025	25	CD4511	2.50	74C173	2.60
CD4027	69	CD4518	2.50	74C193	2.75
CD4028	1.65	CD4566	3.00	74C195	2.75
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LM311N	90	NE531H	3.00	MC5558V	1.00
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LM320K-5	1.35	NE550N	79	80388	4.95
LM320K-5.2	1.35	NE555V	39	LM75450	49
LM320K-12	1.35	NE560B	5.00	75451CN	39
LM320K-15	1.35	NE561B	5.00	75452CN	39
LM320T-5	1.75	NE562B	5.00	75453CN	39
LM320T-5.2	1.75	NE565H	1.25	75454CN	39
LM320T-8	1.75	NE565N	1.25	75491CN	79
LM320T-12	1.75	NE566CN	1.25	75492CN	89
LM320T-15	1.75	NE567H	1.95	75494CN	89
LM320T-18	1.75	NE567V	1.50	RCA LINEAR	
LM320T-24	1.75	LM703CN	45	CA3013	2.15
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LM324N	1.80	LM709N	29	CA3035	2.48
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LM340K-5	1.95	LM711N	39	CA3046	1.30
LM340K-6	1.95	LM723H	55	CA3059	3.25
LM340K-8	1.95	LM723N	55	CA3060	3.25
LM340K-12	1.95	LM733N	1.00	CA3080	85
LM340K-15	1.95	LM739N	1.00	CA3081	2.00
LM340K-18	1.95	LM741CH	35	CA3082	2.00
LM340K-24	1.95	LM741CN	35	CA3083	1.60
LM340T-5	1.75	LM741-14N	39	CA3086	85
LM340T-6	1.75	LM747H	79	CA3089	3.75
LM340T-8	1.75	LM747N	79	CA3091	10.20
LM340T-12	1.75	LM748H	39	CA3123	2.15
LM340T-15	1.75	LM748N	39	CA3130	1.39
LM340T-18	1.75	LM1303N	90	CA3140	1.25
LM340T-24	1.75	LM1304N	1.19	CA3600	1.75
LM350N	1.00	LM1305N	1.40	RC4194	5.95
LM351CN	65	LM1307N	85	RC4195	3.25

74LS00 TTL

74LS00	29			74LS139	1.95
74LS02	29			74LS151	1.55
74LS03	29	74LS74	49	74LS153	1.89
74LS04	35	74LS75	69	74LS157	1.55
74LS05	35	74LS76	49	74LS162	2.25
74LS08	29	74LS83	1.75	74LS163	2.25
74LS10	29	74LS85	2.49	74LS164	1.95
74LS13	69	74LS86	49	74LS175	1.95
74LS14	1.75	74LS90	1.25	74LS181	3.69
74LS20	29	74LS92	1.25	74LS190	2.85
74LS26	39	74LS93	1.25	74LS191	2.85
74LS27	39	74LS95	1.95	74LS192	2.85
74LS28	39	74LS96	1.89	74LS193	2.85
74LS30	29	74LS107	59	74LS194	1.89
74LS32	39	74LS109	59	74LS195	1.89
74LS40	39	74LS112	59	74LS257	1.75
74LS51	29	74LS132	1.25	74LS260	55
74LS55	29	74LS136	59	74LS279	79
74LS73	49	74LS138	1.89	74LS670	3.95

CLOCK CHIPS

MM5309	6 Digit BCD Outputs Reset PIN	$9.95
MM5311	6 Digit BCD Outputs 12 or 24 Hour	4.95
MM5312	4 Digit BCD Outputs 1 PPS Output	4.95
MM5314	6 Digit 12 or 24 Hour 50 or 60 Hz	4.95
MM5316	4 Digit Alarm 1 PPS Output	6.95
MM5318	Video Clock Chip For Use With MM5841	9.95
CT7001	6 Digit Calendar Alarm 12 or 24 Hour	5.95

DATA HANDBOOKS

7400	Pin out & Description of 5400/7400 ICS	$2.95
CMOS	Pin out & Description of 4000 Series ICS	$2.95
Linear	Pin out & Functional Description	$2.95

ALL THREE HANDBOOKS $6.95

FAIRCHILD TECHNOLOGY KITS FAIRCHILD

- Complete Specifications on back of each kit
- Packaged for WALL DISPLAY APPEARANCE
- Dealer's Inquires Invited — Price List Available

DIGITS

FTK0001	0.5" High Common Cathode Digit	$1.00
FTK0002	0.5" High Common Anode Digit	1.00
FTK0003	.357" High Common Cathode Digit	.75
FTK0004	0.8" High Common Cathode Digit	2.00
FTK0005	0.8" High Common Anode Digit	2.00

0.8" HIGH DISPLAY ARRAYS

FTK0010	12 Hour, 3½ Digit Clock Display	7.00
FTK0011	24 Hour, 4 Digit Clock Display	8.00

LED LAMPS

FTK0020	10 Red LED Lamps	1.00
FTK0021	5 Mixed Colored LED Lamps	1.00
FTK0022	10 LED Mounting Clips	1.00
FTK0023	5 Three Piece LED Mounting Adapters	1.00

PHOTO TRANSISTORS

FTK0030	5 Flat Lens Photo Transistors	1.00
FTK0031	5 Round Lens Photo Transistors	1.00
FTK0032	3 Flat Lens Photo Darlingtons	1.00
FTK0033	3 Round Lens Photo Darlingtons	1.00

PHOTO ARRAYS

FTK0040	9-Element Tape Reader Array	16.00
FTK0041	12-Element Card Reader Array	24.00
FTK0042	Reflective Opto Coupler	4.00

COUPLERS

FTK0050	3 General Purpose Opto Couplers	1.00
FTK0051	Darlington Opto Coupler	1.00

MOS CLOCK CIRCUITS

FTK0400	Digital Clock/Calendar Circuit (FCM7001)	7.00
FTK0401	Digital Clock/Calendar with BCD Outputs (FCM7002)	7.00
FTK0402	Direct Drive Digital Clock Circuit with AC Output (FCM3817A)	5.00
FTK0403	Direct Drive Digital Clock Circuit with DC Output (FCM3817D)	5.00
FTK0405	Direct Drive Digital Clock/Calendar Circuit (FCM7015)	6.00

KITS

FTK0106	Automobile Clock Kit	40.00

DISCRETE LEDS

.125" dia.			.90" dia.		
XC209	Red	10/$1	XC111	Red	10/$1
XC209	Green	4/$1	XC111	Green	4/$1
XC209	Orange	4/$1	XC111	Yellow	4/$1
			XC111	Orange	4/$1

.200" dia			.185" dia.			.200" dia.			.085" dia.
XC22	Red	10/$1	XC526	Red	10/$1	XC556	Red	10/$1	MV50
XC22	Green	4/$1	XC526	Green	4/$1	XC556	Green	4/$1	.085" dia. Micro
XC22	Yellow	4/$1	XC526	Yellow	4/$1	XC556	Yellow	4/$1	red LED
XC22	Orange	4/$1	XC526	Orange	4/$1	XC556	Orange	4/$1	6/$1
SSL-22	RT	4/$1	XC526	Clear	4/$1	XC556	Clear	7/$1	

DISPLAY LEDS

DL707 DL338

TYPE	POLARITY	HT		TYPE	POLARITY	HT	
MAN 1	Common Anode	270	2.95	MAN 3620	Common Anode-orange	300	1.75
MAN 2	5 x 7 Dot Matrix	300	4.95	MAN 3640	Common Cathode-orange	300	1.75
MAN 3	Common Cathode	125	.39	MAN 4710	Common Anode-Red	400	1.95
MAN 4	Common Cathode	187	1.95	DL701	Common Anode-red ±	300	.99
MAN 7	Common Anode	300	1.25	DL704	Common Cathode	300	.99
MAN 7G	Common Anode-green	300	1.95	DL707	Common Anode	300	.99
MAN 7Y	Common Anode-yellow	300	1.95	DL 728	Common Cathode	500	1.95
MAN 52	Common Anode-green	300	1.75	DL 747	Common Anode	600	2.25
MAN 64	Common Anode-red	400	1.75	DL 750	Common Cathode	600	2.49
MAN 72	Common Anode	300	1.25	DL 338	Common Cathode	110	.50
MAN 74	Common Cathode	300	1.50	FND70	Common Cathode	250	.75
MAN 82	Common Anode-yellow	300	1.75	FND503	Common Cathode	500	1.00
MAN 84	Common Cathode-yellow	300	1.75	FND507	Common Anode	500	1.00

IC SOLDERTAIL — LOW PROFILE (TIN) SOCKETS

	1-24	25-49	50-100		1-24	25-49	50-100
8 pin	$.17	16	15	24 pin	$.38	37	36
14 pin	20	19	18	28 pin	45	44	43
16 pin	22	21	20	36 pin	60	59	58
18 pin	29	28	27	40 pin	63	62	61
22 pin	37	36	35				

SOLDERTAIL STANDARD (TIN)

14 pin	$.27	25	24	28 pin	$.99	90	81
16 pin	30	27	25	36 pin	1.39	1.26	1.15
18 pin	35	32	30	40 pin	1.59	1.45	1.30
24 pin	49	45	42				

SOLDERTAIL STANDARD (GOLD)

8 pin	$.30	27	24	24 pin	$.70	63	57
14 pin	35	32	29	28 pin	1.10	1.00	90
16 pin	38	35	32	36 pin	1.75	1.40	1.26
18 pin	52	47	43	40 pin	1.75	1.59	1.45

WIRE WRAP SOCKETS (GOLD) LEVEL #3

10 pin	$.45	41	37	24 pin	$1.05	95	85
14 pin	39	38	37	28 pin	1.40	1.25	1.10
16 pin	43	42	41	36 pin	1.59	1.45	1.30
18 pin	75	68	62	40 pin	1.75	1.55	1.40

PUSH BUTTON SWITCH

PB-123 $1.75
Maintained Action Switch
PB-126 $1.75
Momentary Action Switch

SPDT

MINATURE TOGGLE SWITCH

JMT-221	DPDT	on/off/on	$1.95
JMT-223	DPDT	on/none/on	$1.75
JMT-121	SPDT	on/off/on	$1.50
JMT-123	SPDT	on/none/on	$1.25

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NEW LED MOUNTING SYSTEM — to be used with XC556 LEDS — SPECIFY COLORS — **4/$1.00**
RED — GREEN — AMBER — YELLOW

50 PCS. RESISTOR ASSORTMENTS $1.75 PER ASST.

ASST. 1	5 ea.	10 OHM 27 OHM	12 OHM 33 OHM	15 OHM 39 OHM	18 OHM 47 OHM	22 OHM 56 OHM	1/4 WATT 5% - 50 PCS.
ASST. 2	5 ea.	68 OHM 180 OHM	82 OHM 220 OHM	100 OHM 270 OHM	120 OHM 330 OHM	150 OHM 390 OHM	1/4 WATT 5% - 50 PCS.
ASST. 3	5 ea.	470 OHM 1.2K	560 OHM 1.5K	680 OHM 1.8K	820 OHM 2.2K	1K 2.7K	1/4 WATT 5% - 50 PCS.
ASST. 4	5 ea.	3.3K 8.2K	3.9K 10K	4.7K 12K	5.6K 15K	6.8K 18K	1/4 WATT 5% - 50 PCS.
ASST. 5	5 ea.	22K 56K	27K 68K	33K 82K	39K 100K	47K 120K	1/4 WATT 5% - 50 PCS.
ASST. 6	5 ea.	150K 390K	180K 470K	220K 560K	270K 680K	330K 820K	1/4 WATT 5% - 50 PCS.
ASST. 7	5 ea.	1M 2.7M	1.2M 3.3M	1.5M 3.9M	1.8M 4.7M	2.2M 5.6M	1/4 WATT 5% - 50 PCS.

ASST. 8R Includes Resistor Assortments 1-7 (350 PCS.) **$10.95 ea.**

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- Weighs ONLY 11 Ounces
- Wraps 30 AWG Wire onto Standard DIP Sockets (.025 inch)
- Complete with built-in bit and sleeve

$34.95
(batteries not included)

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WRAP • STRIP • UNWRAP

- Tool for 30 AWG Wire
- Roll of 50 ft. White 30 AWG Wire
- 50 pcs. each 1", 2", 3" & 4" lengths — pre-stripped white wire

$11.95

WIRE WRAP TOOL WSU-30

WRAP • STRIP • UNWRAP - $5.95

WIRE WRAP WIRE — 30 AWG

25 ft. min. $1.25 50 ft. $1.95 100 ft. $2.95 1000 ft. $15.00
SPECIFY COLOR — White - Yellow - Red - Green - Blue - Black

THUMBWHEEL SWITCHES

THUMBWHEEL SWITCH ONLY

Part No.	Description	Price
SF 12	Single Pole 10 Position	$2.50
SR 12	Decimal	3.00
SF 21	10 Position BCD only	2.50
SR 21		3.00

Ordering: Order desired switch or switches and add necessary accessories for your particular application

SF - Front Mount SR - Rear Mount

SERIES SF Front Mount Assembly
SERIES SR Rear Mount Assembly

ACCESSORIES

Part No.	Description	Price
SF EP	End Plate (Pair)	.50
SF DP	Divider Plate (each)	.40
SF BB	Blank Body (each)	.40
SF HB	Half Body (each)	.40

ACCESSORIES

Part No.	Description	Price
SR EP	End Plates (pair)	$.50
SR DP	Divider Plate (each)	.40
SR BB	Blank Body (each)	.40
SR HB	Half Body (each)	.40

DIP SWITCH

These switches feature seven SPST slide switches in a molded dip. They are ideally suited for microprocessor applications.

$1.95

ZENERS — DIODES — RECTIFIERS

TYPE	VOLTS	W	PRICE	TYPE	VOLTS	W	PRICE
1N746	3.3	400mm	4/1.00	1N4005	600 PIV	1 AMP	10/1.00
1N751A	5.1	400m	4/1.00	1N4006	800 PIV	1 AMP	10/1.00
1N752	5.6	400m	4/1.00	1N4007	1000 PIV	1 AMP	10/1.00
1N753	6.2	400m	4/1.00	1N3600	50	200m	6/1.00
1N754	6.8	400m	4/1.00	1N4148	75	10m	15/1.00
1N959	8.2	400m	8/1.00	1N4154	35	10m	12/1.00
1N965B	15	400m	4/1.00	1N4305	75	25m	20/1.00
1N5232	5.6	500m	28	1N4734	5.6	1w	28
1N5234	6.2	500m	28	1N4735	6.2	1w	28
1N5235	6.8	500m	28	1N4736	6.8	1w	28
1N5236	7.5	500m	28	1N4738	8.2	1w	28
1N456	25	40m	6/1.00	1N4742	12	1w	28
1N458	150	7m	6/1.00	1N4744	15	1w	28
1N485A	180	10m	6/1.00	1N1183	50 PIV	35 AMP	1.60
1N4001	50 PIV	1 AMP	12/1.00	1N1184	100 PIV	35 AMP	1.70
1N4002	100 PIV	1 AMP	12/1.00	1N1185	150 PIV	35 AMP	1.50
1N4003	200 PIV	1 AMP	12/1.00	1N1186	200 PIV	35 AMP	1.80
1N4004	400 PIV	1 AMP	12/1.00	1N1188	400 PIV	35 AMP	3.00

SCR AND FW BRIDGE RECTIFIERS

C36D	15A @ 400V	SCR	$1.95
C38M	35A @ 200V	SCR	1.95
2N2328	1.6A @ 200V	SCR	.50
MDA 980-1	12A @ 50V	FW BRIDGE REC.	1.95
MDA 980-3	12A @ 200V	FW BRIDGE REC.	1.95

TRANSISTORS

MPS A05	5/$1.00			PN4249	4/$1.00
MPS A06	5/$1.00			PN4250	4/$1.00
2N2219A	3/$1.00	PN3567	3/$1.00	2N4400	4/$1.00
2N2221	4/$1.00	PN3568	4/$1.00	2N4401	4/$1.00
2N2222A	5/$1.00	PN3569	4/$1.00	2N4402	4/$1.00
2N2369	5/$1.00	2N3704	5/$1.00	2N4403	4/$1.00
2N2369A	4/$1.00	2N3705	5/$1.00	2N4409	5/$1.00
PN2415	5/$1.00	2N3706	5/$1.00	2N5086	4/$1.00
2N2484	4/$1.00	2N3707	5/$1.00	2N5087	4/$1.00
2N2906A	4/$1.00	2N3711	5/$1.00	2N5088	4/$1.00
2N2907A	5/$1.00	2N3724	$.65	2N5089	4/$1.00
2N2925	5/$1.00	2N3725	$1.00	2N5129	5/$1.00
2N3053	2/$1.00	2N3903	5/$1.00	2N5138	5/$1.00
2N3055	$.89	2N3904	4/$1.00	2N5139	5/$1.00
MJE3055	$1.00	2N3905	4/$1.00	2N5209	5/$1.00
MJE2955	$1.25	2N3906	4/$1.00	2N5951	5/$1.00
2N3392	5/$1.00	2N4013	3/$1.00	C106B1SCR	2/$1.00
2N3398	5/$1.00	2N4014	3/$1.00	2N5432	$2.00
		2N4123	10/$1.00		

CAPACITOR CORNER

50 VOLT CERAMIC DISC CAPACITORS

	1-9	10-49	50-100		1-9	10-49	50-100
10 pf	.05	.04	.03	.001µF	.05	.04	.035
22 pf	.05	.04	.03	.0047µF	.05	.04	.035
47 pf	.05	.04	.03	.01µF	.05	.04	.035
100 pf	.05	.04	.03	.022µF	.06	.05	.04
220 pf	.05	.04	.03	.047µF	.06	.05	.04
470 pf	.05	.04	.035	.1µF	.12	.09	.075

100 VOLT MYLAR FILM CAPACITORS

.001mf	.12	.10	.07	.022mf	.13	.11	.08
.0022	.12	.10	.07	.047mf	.21	.17	.13
.0047mf	.12	.10	.07	.1mf	.27	.23	.17
.01mf	.12	.10	.07	.22mf	.33	.27	.22

+20% DIPPED TANTALUMS (SOLID) CAPACITORS

.1/35V	.28	.23	.17	1.5/35V	.30	.26	.21
.15/35V	.28	.23	.17	2.2/25V	.31	.27	.22
.22/35V	.28	.23	.17	3.3/25V	.31	.27	.22
.33/35V	.28	.23	.17	4.7/25V	.32	.28	.23
.47/35V	.28	.23	.17	6.8/25V	.36	.31	.25
.68/35V	.28	.23	.17	10/25V	.40	.35	.29
1.0/35V	.28	.23	.17	15/25V	.63	.50	.40

MINIATURE ALUMINUM ELECTROLYTIC CAPACITORS

Axial Lead				Radial Lead			
.47/50V	.15	.13	.10	.47/25V	.15	.13	.10
1.0/50V	.16	.14	.11	.47/50V	.16	.14	.11
3.3/50V	.15	.13	.10	1.0/16V	.15	.13	.10
4.7/25V	.16	.14	.12	1.0/25V	.16	.14	.11
10/25V	.15	.13	.10	1.0/50V	.16	.14	.11
10/50V	.16	.14	.12	4.7/16V	.15	.13	.10
22/25V	.17	.15	.12	4.7/25V	.15	.13	.10
22/50V	.24	.20	.18	4.7/50V	.16	.14	.11
47/25V	.19	.17	.15	10/16V	.14	.12	.09
47/50V	.25	.21	.19	10/25V	.15	.13	.10
100/25V	.24	.20	.18	10/50V	.16	.14	.12
100/50V	.35	.30	.28	47/50V	.24	.21	.19
220/25V	.32	.28	.25	100/16V	.19	.15	.14
220/50V	.45	.41	.38	100/25V	.24	.20	.18
470/25V	.33	.29	.27	100/50V	.35	.30	.28
1000/16V	.55	.50	.45	220/16V	.23	.17	.16
2200/16V	.70	.62	.55	470/25V	.31	.28	.26

More Details? CHECK—OFF Page 118

TS-1 MICROMINIATURE ENCODER-DECODER

- ☐ Available in all EIA standard tones 67.0Hz-203.5Hz
- ☐ Microminiature in size, 1.25x2.0x.65" high
- ☐ Hi-pass tone rejection filter on board
- ☐ Powered by 6-16vdc, unregulated, at 3-9ma.
- ☐ Decode sensitivity better than 10mvRMS, bandwidth, ±2Hz max., limited
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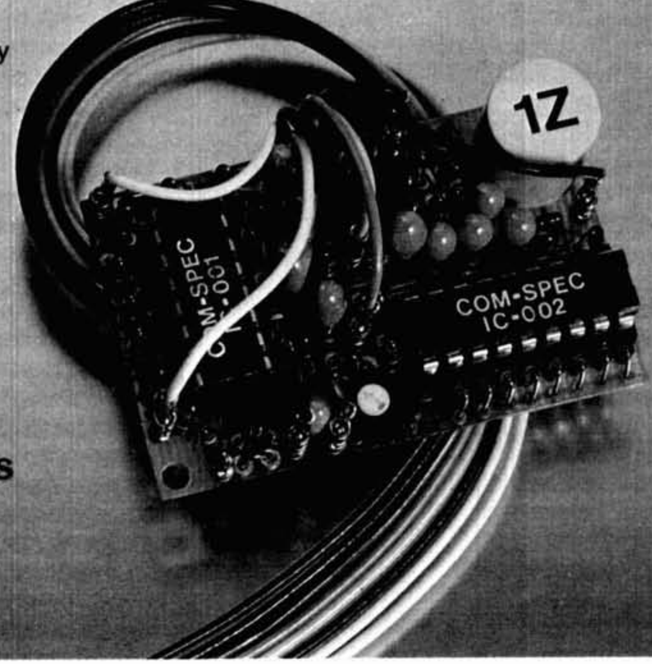
- ☐ Frequency accuracy, ±.25Hz, frequency stability ±.1Hz
- ☐ Encodes continuously and simultaneously during decode, independent of mike hang-up
- ☐ Totally immune to RF



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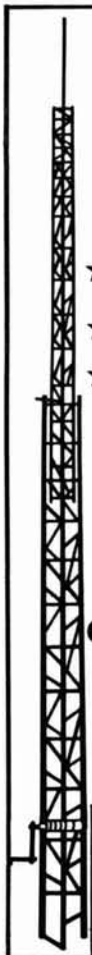

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More Details? CHECK—OFF Page 118

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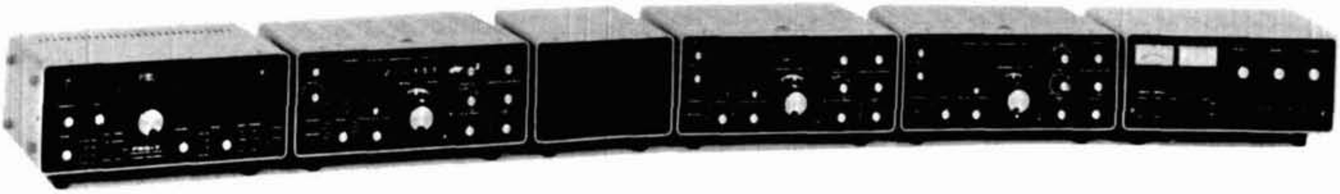
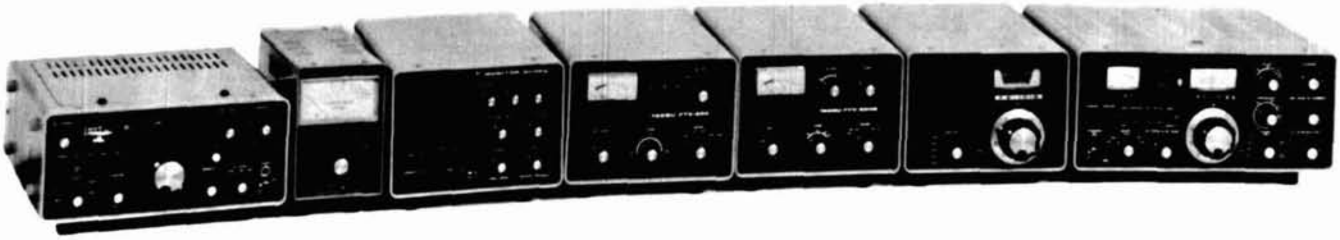
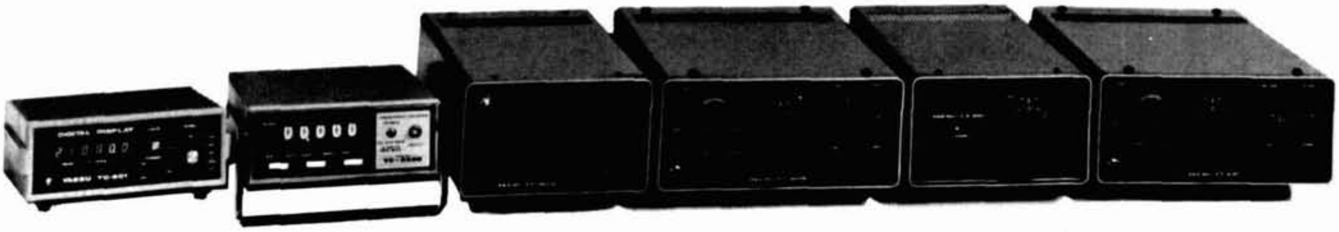


Left to right – FRG-7, Solid State Synthesized Communications Receiver • FR-101 Digital, Solid State Receiver • SP-101B, Speaker • FR-101, Digital Solid State Receiver • FL-101, 100 W Transmitter • FL-2100B, 1200 W PEP Input Linear Amplifier



Left to right – FT-620B, 6 Meter Transceiver • YP-150, Dummy Load Wattmeter • YO-100, Monitor Scope • FTV-250, 2 Meter Transverter • FTV-650, 6 Meter Transverter • FV-101B, External VFO • FT-101E 160-10 M Transceiver



Left to right – YC-601, Digital Frequency Display • YC-355D, Frequency Counter • FP-301, AC Power Supply • FT-301S Digital, All Solid State Transceiver • FV-301, External VFO • FT-221, 144-148 All Solid State All Mode Transceiver

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flea market

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SYNTHESIZER. See Ham Radio, July 76, pg. 20-23, figures 21 to 24. Kit for $115, assembled and tested, $140. Power supply to run from 117 volts additional $15.00. CTD, P. O. Box 708, Cambridge, MA 02139.

VARIABLE AND TRIMMER CAPACITORS — Millen, Johnson, Hammarlund, Erie, Arco. In stock for immediate shipment. Send first class stamp for expanded price list. D & V Radio Parts, 12805 W. Sarle Rd., R#2, Freeland, Michigan 48623.

SAVE! Bomar FM, xtals $4.00 ppd. Dentron, Hustler, CushCraft, W. M. Nye, Ameco. Used gear. Complete catalog - write Ferris Radio, 308 E. Harry, Hazel Park, Mich. 48030.

HW-101 WITH HP-23B. Both less than one year old, perfect, professionally wired, $350. WA5INP, Art Smith, 5446 Grafton Street, Jackson, Mississippi 39206.

WANTED: Navy or McElroy Key. "Don't let yours go silent" (we will love it and use it). Also 1920s microphone. K4NBN, Del Popwell, 1946 Sweetbriar Ln., Jacksonville, Fla. 32217.

CRYSTALS — S.A.S.E. my list. K8LJQ, 355 Mower Rd., Pinckney, Mich. 48169.

RECONDITIONED TEST EQUIPMENT for sale. Catalog $.50. Walter, 2697 Nickel, San Pablo, Ca. 94806.

4-400A's NEW, BOXED, $22. Perfect for 2kw linear. Barnes, 2110 Apache Ridge Rd., Meridian, MS 39301.

TRAVEL-PAK QSL KIT — Send call and 25¢; receive your call sample kit in return. Samco, Box 203, Wyantskill, N. Y. 12198.

CANADIANS. 1,000,000 surplus parts. Bargains galore. Free catalog. ETCO-HR, Box 38, Dorion, Quebec J7V 5V8.

MOBILE IGNITION SHIELDING provides more range with no noise. Available most engines. Many other suppression accessories. Literature, Estes Engineering, 930 Marine Dr., Port Angeles, WA 93862.

WANTED: Collins 51S-1, R390-A, 51J-3. John Callan, 65 Beechcroft St., Brighton, Ma. 02135.

LOOKING FOR USED GEAR? Buyers & Sellers radio brokerage has the equipment you want at the right prices. Call our Ham Gear Hotline 617-536-8777 Monday-Friday, 9-9.

BUY — SELL — TRADE. Write for free mailer. Give name, address and call letters. Complete stock of major brands new and reconditioned equipment. Call for best deals. We buy Collins, Drake, Swan, etc. SSB & FM. Associated Radio, 8012 Conser, Overland Park, Kansas 66204. 913-381-5901.

FREE Electronics Surplus Catalog. Electronic Specialties, 1659 Wetmore, Tucson, AZ 85705.

QSL's, CATALOG 30¢. RTTY paper 4½ inch rolls white, case of 12 $25.00 plus shipping. P. O. Box 11184, Phoenix, Arizona 85061.

MOBILE BONDING STRAPS under 50¢ each. Literature. Estes Engineering, 930 Marine Drive, Port Angeles, Wash. 98362.

STOP LOOKING for a good deal on amateur radio equipment — you've found it here — at your amateur radio headquarters in the heart of the Midwest. We are factory-authorized dealers for Kenwood, Drake, Collins, ICOM, Ten-Tec, Atlas, Tempo, Regency, Swan, Midland, Alpha, Standard, Dentron, Hy-Gain, Mosley, CushCraft, and CDE, plus accessories. For the best deal around on HF and VHF gear, write or call us today for our low quote and become one of the many happy and satisfied customers of Hoosier Electronics, P. O. Box 2001, Terre Haute, Indiana 47802. (812) 238-1456.

FERRITE BEADS: w/specification and application sheet - 10/$1.00. Assorted PC pots - 5/$1.00. Miniature mica trimmers, 3-40 pf. - 5/$1.00. Postpaid. Includes latest catalog. Stamp for catalog alone. CPO Surplus, Box 189, Braintree, MA 02184.

NEW ADJUSTABLE THREE OUTPUT REGULATED POWER SUPPLY, plus 900 parts worth $400.00 list. Solid state TV recorder electronic unit. Schematics, parts cross reference. Free brochure. $17.95 plus $3.50 S&H, USA. Master Charge, BankAmericard. Satisfaction guaranteed. Madison Electronics Company, Incorporated, Box 369, D77, Madison, Alabama 35758.

ETCH IT YOURSELF PRINTED CIRCUIT KIT, Photo-Positive Method — All the supplies for four P.C. boards, direct from magazine article in less than 2 hours. Only $19.95. S.A.S.E. for details. Excel Circuits, P. O. Box 891, Troy, Michigan 48099, 313-549-0440.

COMMUNICATIONS PUBLICATIONS and frequency lists: Military, government, police, aviation, maritime and more. HF and VHF. Voice & RTTY. Catalog 25¢. Handler, Box CC, Northfield, Illinois 60093.

FOR SALE: Gertsch FM7-DM3 frequency meter-deviation meter, recently calibrated, $575. Six G.E. KY-5 cavities, excellent condition, $300 for the set. WAØNUX, P. O. Box 70, Springfield, SD 57062.

MODERN CODE PRACTICE. 0-22wpm on four 60 min. cassettes, $10. Royal, P. O. Box 2174, Sandusky, Ohio 44870.

FIGHT TVI with the RSO Low Pass Filter. For brochure write: Taylor Communications Manufacturing Company, Box 126, Agincourt, Ontario, Canada. MIS 3B4.

NAMEBADGES - $1.50 - Name and call sign $2.00. Engraved plastic with pin, clutches or adhesive. Black, white, red, blue. Include payment with order. Special prices on club badges and hamfest plaques. Donan Engraving. P. O. Box 07155, Lakewood, Colo. 44107.

RTTY CLOSEOUT — NS-1A PLL TU while they last. Wired/tested $24.95. Board $3.00. All postpaid. SASE for info. Nat Stinnette Electronics, Tavares, FL 32778.

flea market

MOTOROLA HT220, HT200, and Pageboy service and modifications performed at reasonable rates. WA4FRV, (804) 320-4439 evenings.

TECH MANUALS for Govt. surplus gear — $6.50 each: SP-600JX, URM-25D, OS-8A/U, PRC-8, 9, 10. Thousands more available. Send 50¢ (coin) for 22-page list. W3IHD, 7218 Roanne Drive, Washington, D. C. 20021.

RUBBER STAMP, name/call/QTH $2.50 ppd. (CA residents add tax). LWM Press, Box 22161, San Diego, CA 92122.

SELLING: KLM ECHO II — SSB/CW trnscvr 2 mtr, mint, $300.00. G.E. Progline 60 W. 2 mtr FM, w/extra xtals & tubes, $150.00. Hammarlund SP 600-JX-17, communications rcvr, $200.00. R. D. Pray, WA2PPH, RD#2, W. Chazy, N. Y. 12992. (518) 493-5193.

HEATHKIT COMBO AMP LESS SPEAKERS (TA-17). Trade for a good 2 mtr rig. Tony Harkey, Rt. 2, Bankston, Alabama (205-689-4817).

TELETYPEWRITER PARTS, gears, manuals, supplies, tape, toroids. SASE list. Typetronics, Box 8873, Ft. Lauderdale, Fl. 33310. Buy parts, late machines.

WANTED — Duo bander 2 and PS made by W.R.L. Cost? WA3YPB, 2 Granite Road, Levittown, Pa. 19057.

FREE CATALOG. Calculators, digital thermometers, ultrasonics, kits, strobes, ni-cads, LED's, transistors, IC's, unique components. Chaney's Box 27038, Denver, Colo. 80227.

PORTA-PAK the accessory that makes your mobile really portable. $67.50 and $88.00. Dealer inquiries invited. P. O. Box 67, Somers, Wisc. 53171.

FOR SALE: Misc. ARC and Collins equipment. Send SASE for list. Jerry Keelin, 409 S. Oklahoma, Shamrock, TX. 79079.

LARSEN ANTENNAS (our specialty) 2,432 magnetic, trunk-lip 5/8 $33.00, 5/8 ground plane $45.00. BankAmericard and Mastercharge accepted. 201-962-4695. Narwid Electronics, 61 Bellot Road, Ringwood, NJ 07456.

SELL — Touch tone encoder, CMOS MC-14410P chip, complete with keyboard and crystal. Functional subminiature, assembled, $25. Printed circuit board for above, 1.2" x 0.8", $1.25. The WA4DSY HT220 synthesizer, assembled and functional, $125 or trade for an HT220 board in working condition, tuneable to 146 MHz. Regency HR2A, excellent condition, unmodified, $125. Knight VOM KG-640, mint, $20. Heath 2M, ⅝ wave mobile antenna, never used, $12. Drake low pass filter, TV-100, $5. Slinky dipole, $20. Motorola RF transistors, new, sealed, 2N5642, 2N5643, $5 each. Will ship within U.S. Send S.A.S.E. for info. WA9WDB/P5, John Teles, 10511 Tenneco, Houston, Texas 77099.

QRP TRANSMATCH for HW7, Ten-Tec, and others. Send stamp for details to Peter Meacham Associates, 19 Loretta Road, Waltham, Mass. 02154.

ROBOT LINE CAMERA 80A w/1.9 lens focus down to 6 inches. Monitor 70A. Make offer. K9GBN, 122 Arrow Dr., Pekin, Illinois 61554.

SYNTHESIZER, see Ham Radio, July 76, pg. 20-23, figures 21-24. Kit for $115. Assembled and tested, $140. Power supply to run from 117V additional $15. CTD, P. O. Box 708, Cambridge, MA 02139.

MONUMENT HILL, LaGrange, Texas Repeater is operating on 16/76. Our range is not fantastic, but you're welcome to try us if you travel Highways 77, 71, 290, or I-10. WA5AAO.

RTTY DEMODULATORS — Immediate delivery. New ST-5's with auto-start and AK-1 AFSK audio oscillator. $185 or $25 and balance UPS COD. David Tancig, 618 W. White St., Champaign, Ill. 61820.

WANTED: Drake T-4 Reciter, consider mint SBE 33 or Swan MB 40 if price right. WA5AAO, Box 335, LaGrange, TX 78945.

WANTED: Car telephones and mobile telephone parts, heads, cables, etc. Greg Hyman, 87 Yonkers Ave., Yonkers, N. Y. 10701. 914-476-4330.

B & K TEST EQUIPMENT. 15% discount. Free shipping. Free catalog. Spacetron, Box 84-T, Broadview, IL 60153.

MANUALS for most ham gear, 1939/70. List $1.00. Send SASE (or 25¢) for one specific model quote. Hobby Industry, WØJJK, Box H864, Council Bluffs, Iowa 51501.

STAINLESS AND GALVANIZED STEEL antenna guy wire our specialty. Wilcox Electronics, Box 1331, S. L. C., Utah 84110.

More Details? CHECK—OFF Page 118

SPECIALS FROM MHz electronics

Fairchild VHF Prescaler Chips

11C01FC	High Speed Dual 5-4 Input no/nor	15.40
11C05DC	1 GHz Counter Divide by 4	74.35
11C05DM	1 GHz Counter Divide by 4	110.50
11C06DC	UHF Prescaler 750 MHz D Type flip/flop	12.30
11C24DC	Dual TTL VCM same as MC4024P	2.60
11C44DC	Phase Freq. Detector same as MC4044P	2.60
11C58DC	ECL VCM	4.53
11C70DC	600 MHz flip/flop with reset	12.30
11C83DC	1 GHz 248/256 Prescaler	29.20
11C90DC	650 MHz Prescaler Divide by 10/11	16.00
11C90DM	same as above except Mil. version	24.00
11C91DC	605 MHz Prescaler Divide by 5/6	16.00
11C91DM	same as above except Mil. version	24.00
95H90DC	350 MHz Prescaler Divide by 10/11	9.50
95H90DM	same as above except Mil. version	16.50
95H91DC	350 MHz Prescaler Divide by 5/6	9.50
95H91DM	same as above except Mil. version	16.50

GIAY-3-8500 Game Chip 29.95
T.I. TMS4060/C2107, 4K RAM 19.01

Batteries
NI-CAD's AA cells 1.25 volts at 500 mahr. $0.49
Gel-Cell 12 volts at 1.5 Amp Hr. #GC-1215 $19.95

Crystals

1.000000 MHz	4.95
5.000000 MHz	4.95
3579.545 KC	2.95

JUST ARRIVED! These radios have just been pulled out of service. Set up for approx. 150 MHz. Clean. All tubes included. No accessories. Prices FOB Phoenix.

Motorola U43 GGT	$49.95
GE TPL	$99.95
GE MT-33	$39.95

G.E.L. FM Broadcast Exciter (Stereo) contains the following: 1 ea. Model FM100, FM200, FM400A, FM600, FM800A, and SC200 $299.00

NEW
Motorola, Motorcycle Radio — Model T33BAT $39.95 FOB Phoenix

Motorola MC14410CP CMOS tone Generator uses 1 MHz Crystal to produce standard dual frequency telephone dialing signal. Directly compatible with our 12 key Chomeric pads. Kit includes the following.
1 MC14410CP
1 Touch Tone Pad
1 1 MHz Crystal
1 Printed Circuit Board (From Ham Radio Sept. 1975)
And all other parts for assembly.
$19.95

Fairchild 95H90DC Prescaler divide by 10 to 350 MHz. Will take any 35 MHz Counter to 350 MHz. Kit includes the following.
1 95H90DC
1 2N5179
2 UG-88/u BNC's
1 Printed Circuit Board
And all other parts for assembly.
$29.95

Fairchild 11C90DC Prescaler divide by 10 to 650 MHz. Will take any 65 MHz Counter to 650 MHz or with a 82S90 it will divide by 10/100 to 650 MHz. This will take a 6.5 MHz counter to 650 MHz. Kit includes the following.
1 11C90DC
1 2N5179
2 UG-88/U
1 MC7805CP
1 Bridge
1 Printed Circuit Board and all other parts for assembly.
82S90 add $5.70 to total.
$59.95

Fairchild 3817 Clock Kit from Ham Radio, Feb. 1976, Pg. 26 — All parts included except transformer and case. 12 hour $24.95 24 hour $29.95

I.C.'s

8223B	$3.00
2102	$1.99

MuRata 10.7 MHz Ceramic Filters #SFW-10.7MA $3.95

Johanson Trimmer Capacitors

.6 to 6 pf.	$1.95
1 to 14 pf.	$1.95
1 to 20 pf.	$1.95

Ferrite Beads
12 for .99 or 120 for 9.99

FET's

2N3070	1.50	2N5460	.90	MFE3002	3.35
2N3436	2.25	2N5465	1.35	MPF102	.45
2N3458	1.30	2N5565	5.45	MPF121	1.50
2N3821	1.60	3N126	3.00	MPF4391	.80
2N3822	1.50	MFE2000	.90	U1282	2.50
2N4351	2.85	MFE2001	1.00	MMF5	5.00
2N4416	1.05	MFE2008	4.20	40673	1.39
2N4875	1.75	MFE2009	4.80	40674	1.49

TUBES

2E26	4.00	811A	7.95	7984	4.95
3B28	4.00	931A	11.95	8072	32.00
4X150A	15.00	5849	32.00	8156	3.95
4X150G	18.00	6LQ6	$4.50	8908	9.95
4CX250B	24.00	6146A	4.75	8950	5.50
4CX350A/8321	35.00	6146B/8298A	5.75	4-400A	29.95
4CX15000A	$150.00	6360	7.95	4-250A	24.95
DX415	25.00	6907	35.00	4-125A	20.95
572B/T160L	25.00	7377	40.00	4-65A	15.95

TRANSFORMERS

F-18X	6.3vct at 6 amps	3.56
F-93X	6.5v to 40v at 750 ma.	3.53
F-92A	6.5v to 40v at 1 amp	4.59
F-91X	6.5v to 40v at 300 ma.	2.72
N-51X	Isolation 115vac at 35va.	2.80
Model D-2	6.5v at 3.3 amps	4.95
	6.5v at 3.3 amps	
C-912-034	22vct at 200 ma.	
	11v at 250 ma.	1.49
BE-12433-001	30v at 15 ma.	.49
C-404-024	18vct at 400 ma.	1.49
BGH-9	6.3vct at 10 amps.	6.95
F-107Z	12V @ 4A or 24 V @ 2A	7.80
P6377	12v @ 4a or 24v @ 2a	6.31
P6378	12v @ 8a or 24v @ 4a	10.31
P8196	80vct @ 1.2a	6.28

Erie High Voltage Power Supply

TSK-209-000
Input 24vdc
output #1 100 vdc − 12.95
#2 400 vdc +
#3 15000 vdc
Size: 3½″ x 2″ x 2¾″
This power supply was used in a CRT Terminals

DIODES

1N270 Germanium Diodes $7.95/c
HEP170, 2.5A, 1000 PIV $4.95/20
Semtech SFMS 20K, 20KV, 10 ma, fast recovery $1.26 ea.

RF TRANSISTORS

2N1561	15.00	2N3866 JAN TX	4.85	2N5590	6.30
2N1562	15.00	2N3924	3.20	2N5591	10.35
2N1692	15.00	2N3925	6.00	2N5635	4.95
2N1693	15.00	2N3927	11.50	2N5636	11.95
2N2631	4.20	2N3948	2.00	2N5637	20.70
2N2857	1.80	2N3950	26.25	2N5643	20.70
2N2876	12.35	2N3961	6.60	2N5641	4.90
2N2880	25.00	2N4072	1.70	2N5643	20.70
2N2927	7.00	2N4073	2.00	2N5764	27.00
2N2947	17.25	2N4135	2.00	2N5841	11.00
2N2948	15.50	2N4427	1.24	2N5842/MM1607	19.50
2N2949	3.90	2N4430	20.00	2N5849/MM1622	19.50
2N2950	5.00	2N4440	8.60	2N5862	50.00
2N3287	4.30	2N4957	6.30	2N5942	49.50
2N3300	1.05	2N5070	13.80	2N5922	10.00
2N3302	1.05	2N5090	6.90	2N6080	5.45
2N3307	10.50	2N5108	3.90	2N6081	8.60
2N3309	3.90	2N5109	1.55	2N6082	11.25
2N3375/MM3375	7.00	2N5177/MRF5177	20.00	2N6083	12.95
2N3553	1.80	2N5179	.68	2N6084	14.95
2N3571	4.10	2N5184		2N6094	5.75
2N3818	6.00	2N5216	47.50	2N6095	10.35
2N3824	3.20	2N5583	5.60	2N6096	19.35
2N3866	1.09	2N5589	4.60	2N6097	28.00
2N3866 JAN	4.14			2N6166	36.80

RF TRANSISTORS

MRF207	2.00	Kertron KB6008	5.50	MM3009	1.80
MRF208	10.20	Amperex BLY90	22.50	MM3375	7.00
MRF209	12.35	Amperex A209	8.60	MM3904	1.50
MRF237	1.85	MSC 2001	20.00	MM3906	1.43
MRF238	8.55	MSC 3000	20.00	MM4000	1.24
MRF450	16.55	MSC 3001	20.00	MM4001	1.39
MRF453	19.55	MSC 80205	20.00	MM4003	1.85
MRF504	6.75	MSC 80206	20.00	MM4036	1.60
MRF509	5.50	MSC 80255	20.00	MM4044	3.00
MRF511	8.60	Fairchild SE7056	3.00	MM4545	3.00
MRF620	27.00	MM1051	2.00	MM8006	2.15
MRF621	30.50	MM1500	32.20	MM1552	50.00
MRF8004	1.90	MM1550	10.00	MM1553	56.50
HEPS3013/75	2.95	MM1601	5.50	HEPS5026	2.48
HEPS3014/76	4.95	MM1602	7.50	MSC 80256	20.00
HEPS3002	11.03	MM1607/2N5842	8.65	CTC D1-28	20.00
HEPS3003	29.88	MM1614	2.75	CTC D10-28	20.00
HEPS3005	9.55	MM1620	17.50	CTC E1-28	20.00
HEPS3006	19.90	MM1622/2N5849	19.50		
HEPS3007	24.95	MM1661	15.00		
HEPS3008	2.18	MM1669	17.50		
HEPS3010	11.34	MM1943	3.00		
RCA TA7994	50.00	MM2605	3.00		
RCA 40290	2.48	MM2608	5.00		
Kertron K2126	5.50	MM3002	1.65		

MHz electronics

2543 N. 32nd STREET
PHOENIX, ARIZONA 85008
PH. 602-957-0786

C.O.D.
OR

More Details? CHECK—OFF Page 118

flea market

QSL'S — BROWNIE W3CJI — 3035B Lehigh. Allentown, Pa. 18103. Samples with cut catalog 50¢.

WANTED: Used SB220 or SB200. 3-24-203, Sakonyama, Yokohama, Japan. Takayoshi Iwama.

FOR SALE: Lampkin 107c Generator. 1 year old, mint condition. Original cost $3,000. Make an offer. Pete Hons, Portage, Pa. 15946. 814-736-3883.

ADCOM MOBILE POWER SUPPLY $35. Edison cylinder phonograph recordings on cassette. S.A.S.E. list. Talen, 0605 Double Spur Loop, Austin, Texas 78759.

HELP FOR YOUR NOVICE, general advanced ticket. Recorded audio-visual theory instruction. Free information. Amateur License Instruction, P. O. Box 6015, Norfolk, Va. 23508.

1 KW. LINEAR (continuous duty amplifier) custom manufactured compact with heavy duty power supply used once, excellent like new - $195 (ship UPS 50 lb.) OUNG, 210 Richardson Ave., San Francisco, CA 94123.

WANTED: Inoperative Collins R-390A to repair and for maintenance of my R-390A. Ed Wagner, 1018 Birch Haven Cir., Monona, WI 53716.

Coming Events

CUYAHOGA FALLS AMATEUR RADIO CLUB ANNUAL AUCTION, Feb. 26. At Stow, Ohio National Guard Armory, 2 p.m. to 10 p.m. Admission $2, no advance ticket sales. Talk in 04/64, 84/24, Channel 2. Call WB8VNO for further information.

LAPORTE WINTER HAMFEST — The LaPorte, Indiana, ARC will hold its Winter Hamfest on the 27th of February, 1977, beginning at 8 a.m. (Chicago time) at the LaPorte Civic Auditorium. Good food, plenty of FREE tables, 50 miles East of Chicago. Talk-in on 01-61 and 94. Donation $2.00 at the gate. Information from LPARC, P. O. Box 30, LaPorte, IN. 46350.

BLOSSOMLAND SWAP-SHOP. Sunday, March 6th. Bridgman Middle School Gym, Bridgman, Michigan. Expanded facilities, refreshments, prizes, fun. Table space restricted to radio and electronic items only. Advance ticket donation $1.50. Tables $2. Write: John Sullivan, P. O. Box 345, St. Joseph, Mich. 49085. Make checks payable to Blossomland A.R.A.

MANSFIELD MID-WINTER HAMFEST AUCTION, February 6, 1977, Richard County Fairgrounds, Mansfield, Ohio. Prizes, flea market, auction. Doors open 8 a.m., talk-in 146.34/94, S2/52. Tickets $1.50 in advance, $2.00 at the door. Contact Harry Frietchen, K8JPF, 120 Homewood, Mansfield, Ohio 44906. 419-529-2801 or 419-524-1441.

MICHIGAN — The 7th Annual Livonia Amateur Radio Club's Swap 'n Shop will be held on Sunday, February 27, 1977, from 8:00 a.m. to 4:00 p.m., at the Stevenson High School in Livonia, Michigan. There will be plenty of tables, door prizes, refreshments, and free parking available. Talk-in on 146.04/.64 and 146.52 Simplex. For further information, write Neil Coffin, WA8GWL, c/o Livonia Amateur Radio Club, P. O. Box 2111, Livonia, Michigan 48150.

W6LS 12th Los Angeles Amateur Radio Convention. Saturday and Sunday, May 21 & 22. 2814 Empire Avenue, Burbank, CA 91605.

STERLING-ROCK FALLS Amateur Radio Society Hamfest. Sunday, March 6, 1977, High School Field House, Sterling, Illinois. Advance ticket $1.50, at door $2.00. Contact Don Van Sant, WA9PBS, 1104 5th Ave., Rock Falls, Ill. 61071.

IOWA: Davenport Radio Amateur Club Hamfest is Sunday, Feb. 27, 1977 at the Masonic Temple in Davenport, Ia. Admission is $1.50 advance, $2.00 at door. Talk in on 28/88 and 52. Refreshments and tables available. For tickets send S.A.S.E. to Dick Lane, WAØGXC, 116 Park Ave., So. Eldridge, Ia. 52748.

Stolen Equipment

TRIO TR220 2 meter fm transceiver s/n 621270 taken on November 23, 1976 along with my 1976 Chevrolet Corvette. The transceiver was not in its case and the on/off volume control was removed and remotely wired from a rear compartment to the center console of the car. If anyone finds both the car and radio, keep the radio and give me the car! Richard C. Bean, WA1KDL.

More Details? CHECK—OFF Page 118

More Details? CHECK–OFF Page 118

FREQUENCY STANDARD

- √ Precision crystal.
- √ Markers at 100, 50, 25, 10, 5 KHz.
- √ Zero adjust sets to WWV.

The Palomar Engineers Frequency Standard gives sharp clear markers throughout the high frequency band from 160 through 6 meters.

With the panel switch in 100 KHz position the markers can be heard every 100 KHz for checking calibration of your receiver, transceiver, or VFO. Additional markers can be turned on with the panel switch every 50, 25, 10 or 5 KHz.

The exclusive Palomar Engineers circuit generates only the wanted markers. No extra "ghost" markers appear.

Connection to your receiver is simple. A twisted-wire capacitor from the Standard to the receiver rf amplifier or mixer. Or a short "antenna" connected to the Standard may radiate enough marker signal.

The Frequency Standard is factory set to frequency and the setting can be checked and adjusted with the "zero" trimmer while listening to WWV or a broadcast station. All markers are as accurate as the WWV calibration, typically .0001%.

Don't take chances; check your frequency. Use the Standard with the wide range of selectable markers, the time- proven Palomar Engineers Frequency Standard.

Send for free brochure.

The price is $37.50 (9-v battery not included) and we deliver postpaid anywhere in the U.S. and Canada. California residents add sales tax. ORDER YOURS NOW!

PALOMAR ENGINEERS

BOX 455, ESCONDIDO, CA 92025
Phone: (714) 747-3343

SPEAKERS

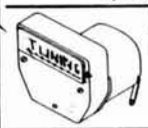
SQUARE — 3" - 4Ω - .3W, 4 mtg holes. $1.45 ea. ppd., 2/$2.75 or 4/ $4.80 ppd.

PIONEER — Round 2¾" x ⅞" - 16Ω - .3W, 4 hole mtg. $1.55 ea., 2/$2.85 or 4/$5.20 ppd.

OVAL — 2" x 4" x 1¼" deep - 8Ω - .1W. 4 Hole Mtg. $1.75 ea. ppd., 2/$3.15 or 4/$5.75 ppd.

Round #5P585A 2" x ¾" - 8Ω - .1W Matsushita. $1.35 ea. ppd. 2/$2.55 or 4/$4.75 ppd.

NOBLE 100K Dual Slide Potentiometer, 2⅞" x ¾" x ¾" with 1⅛" lever. $1.45 ea. or 10 for $12.00 ppd.



TUNING METERS — Blue tinted plastic body, 0 to left, graduated scale, 200μA, 1½"W x 1¼"H x ¾"D. Scale can be rear lighted. Sylvania #18148-1 $2.25 ea. or 4/$6.95 ppd.

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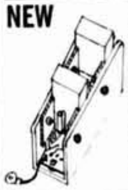

Transistor and Relay Assembly — consists of (2) MJE3055 and (2) MJE2955 transistors (10 amp, 90w, 60v complementary pairs) mounted in "U" channel heat sink 2½" x 1⅛" x 1½". (2) XTAL CAN RELAYS, DPDT, 28v, 8000Ω, 5.8 ma DC, 1 amp contacts mounted on PC board with resistors. $2.95 ea. ppd.

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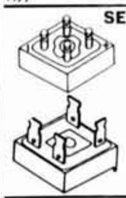

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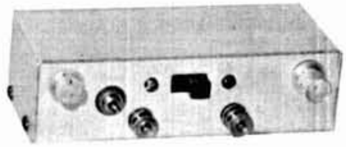

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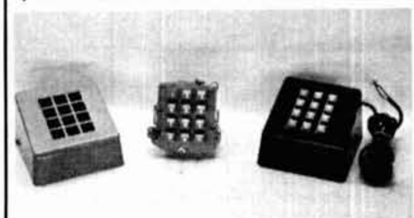

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SPECIAL OF THE MONTH

MADE FOR HOTEL ROOM SERVICE WAKE UP SERVICE

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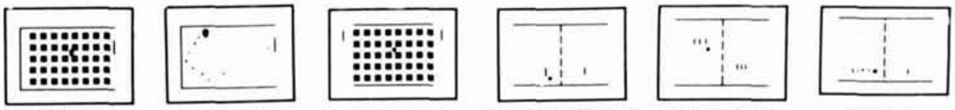

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WIPE OUT the squares — 7 serves from center — 40 squares — 10 pts each square hit by ball. On each serve square disappears when hit by ball. For 1 or 2 players.

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7403	.20	7445	.89	74107	.26	74163	.76
7404	.20	7446	.87	74109	.35	74164	.80
7405	.20	7447	.69	74110	.50	74165	.90
7406	.39	7448	.81	74116	2.00	74166	1.00
7407	.39	7450	.20	74120	1.25	74167	3.00
7408	.20	7451	.20	74121	.34	74170	2.00
7409	.24	7453	.20	74122	.39	74172	9.72
7410	.20	7454	.20	74123	.50	74173	1.25
7411	.20	7460	.20	74125	.45	74174	.85
7412	.24	7470	.20	74126	.45	74175	.75
7413	.35	7472	.23	74128	.65	74176	.85
7414	.70	7473	.26	74132	.95	74177	.85
7416	.33	7474	.29	74136	.50	74180	.75
7417	.33	7475	.39	74141	.80	74181	2.00
7420	.20	7476	.31	74142	4.00	74182	.90
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7423	.28	7480	.69	74144	4.00	74185	1.30
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7426	.24	7483	.75	74147	2.50	74191	.65
7427	.24	7485	.90	74148	1.75	74192	.85
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7430	.20	7489	1.50	74153	.70	74195	.55
7432	.28	7490	.39	74154	.90	74196	.80
7433	.34	7491	.65	74155	.70	74197	.83
7437	.28	7492	.39	74156	.90	74198	1.50
7438	.28	7493	.39	74157	.70	74199	1.75
7439	.36	7494	.70	74158	1.75	74200	3.50
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NORTH SHORE

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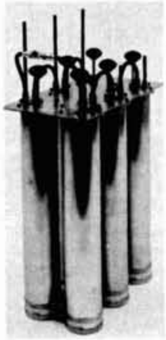

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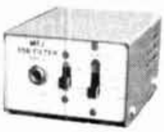

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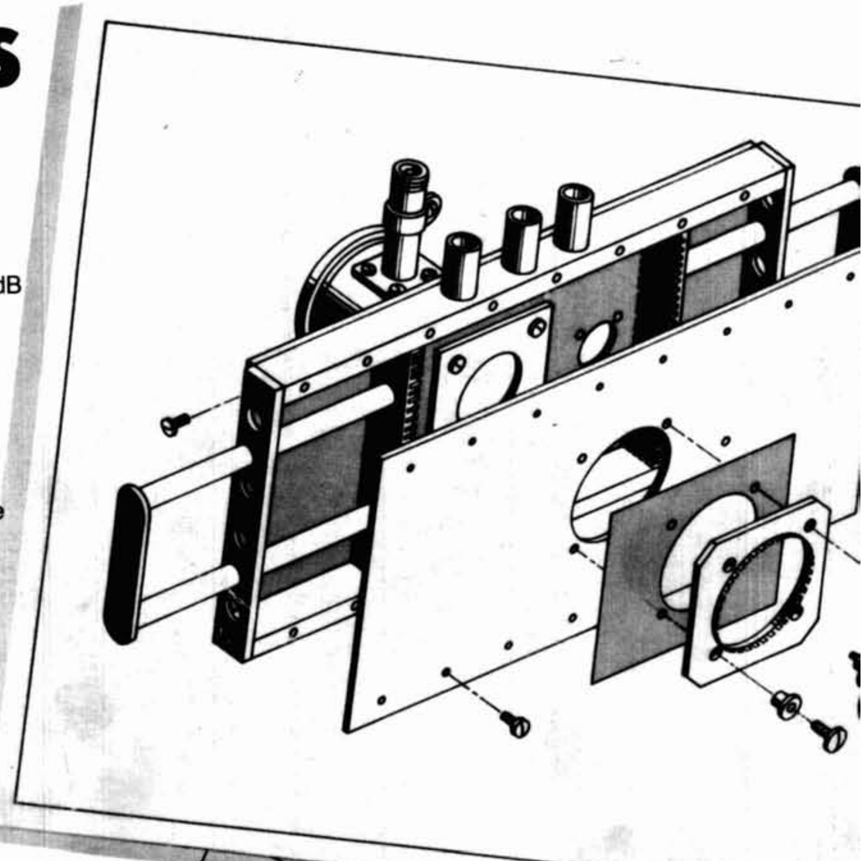

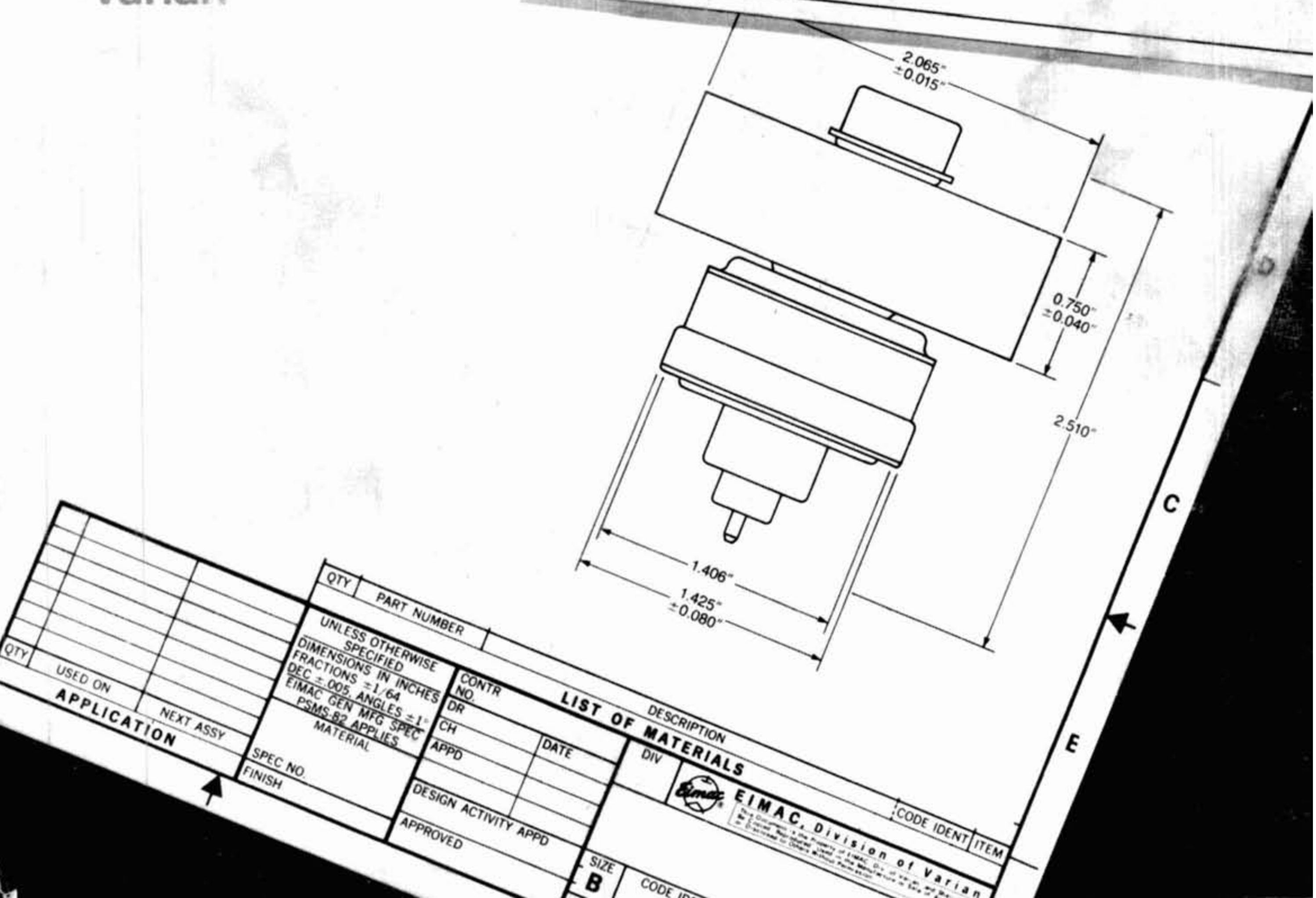

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